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Superfund Record of Decision (EPA Region 2)
Marathon Battery Company Site, Cold Spring
Putnam County, New York, September 1986

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16. ABSTRACT

The Marathon Battery Company (MBC) site, located in the Village of Gold Spring, Putnam County, NY, has two components: the East Foundry Cove Marsh (EFCM), and Constitution Marsh. The site began as a battery manufacturing plant in 1952, producing military and commercial batteries for a period of 27 years. During this time the site property changed ownership and its name several times. It operated as the MBC from 196[illegible] to 1979. Approximately 50,000 kg of cadmium were discharged into the EFCM as a result of MBC's wastewater treatment system. A bypass valve, used during system overloads and shutdowns, diverted flow to EFCM. This occurred at least twice weekly for periods of time ranging from a few hours to a full operating shift. In 1965 the New York State Department of Health ordered the plant to disconnect its industrial discharge from the Village's sanitary sewer upon concluding that the battery plant's process effluent could not be managed by a new proposed sewage treatment system. Accommodating the directive, the plant shut down the diversion pumps and bypassed the entire wastewater flow into the storm sewer to EFCM. Between September 1972 and July 1973 hydraulic dredging of the channel, which connects EFCM to Constitution Marsh, removed approximately 90,000 square meters of sediment. Approximately 4,000 cubic meters of dredged material were then retained in a diked enclosure constructed over a parking lot on the battery facility property. During the dewatering process, the sediments were allowed to settle and the

(See Attached Sheet)

17. KEY WORDS AND DOCUMENT ANALYSIS		
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Superfund Record of Decision:

Marathon Battery, NY

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Record of Decision
Remedial Alternative Selection

Site:

Marathon Battery Company site, Cold Spring, Putnam County, New York

Documents Reviewed:

I am basing my decision primarily on the following documents describing the analysis of the cost-effectiveness of remedial alternatives at the Marathon Battery Company site:

- Remedial Action Master Plan for the Marathon Battery Site, Cold Spring, New York, C.C. Johnson and Associates, August 1982.
- Preliminary Site Background Data Analysis of Foundry Cove, Cold Spring, Putnam County, New York, Resource Engineering, July 1983.
- Marathon Battery Memorandum Regarding Archive Search, Putnam, Hayes and Bartlett, July 1983.
- Archives Search Report of the Former Cold Spring, Battery Plant Putnam County, New York, Environmental Science and Engineering, August 1984.
- Technical Memorandum No. 9, Summary of Hydraulic Monitoring/Data Collection, Marathon Battery Site, ACRES International, February 1985.
- Technical Memorandum No. 7, Summary of Environmental Investigations Sediment and Water Quality Marathon Battery Site, ACRES International, May 1985.
- Technical Memorandum No. 8, Summary of Ecological Investigations, Marathon Battery Site, ACRES International, 1985.
- Draft Remedial Investigation Report, ACRES International, August 1985.
- Technical Memorandum No. 12, Evaluation Summary Off-Site Remediation Alternatives, ACRES International, November 1985.

- Supplemental Remedial Investigation Report, Marathon Battery Comapany site, EBASCO Services, Inc., August 1986.

- Supplemental Feasibility Study Report, Marathon Battery Company site, EBASCO Service, Inc., August 1986.

- Summary of Remedial Action Alternative Selection - Marathon Battery site.

- Responsiveness Summary.

- Staff summaries, memoranda, letters, and Recommendations.

Description of Selected Remedy:

- Pilot plant treatability study to determine an effective treatment scheme for fixating the contaminated sediments.

- Hydraulic dredging of the contaminated sediments from East Foundry Cove Marsh with cadmium concentrations greater than 100 milligrams/kilogram.

- Thickening of the dredged sediments.

- Treatment of thickener supernatant and discharge to the dredge cell.

- Chemical fixation of the thickened sediments.

- Truck transport of the fixated sediments to a local sanitary landfill.

- Restoration of East Foundry Cove Marsh by addition of clean fill, clay with a high affinity for cadmium, and revegetation.

- Diversion of the Kemble Avenue and New York State Department of Transportation storm sewers into East Foundry Cove and Foundry Brook, respectively.

- Long-term monitoring of Constitution Marsh sediments and biota.

- Bioassay sampling in East Foundry Cove to better characterize the link between the levels of cadmium in the sediments and bioaccumulation in aquatic fauna.

- Establishment of an information center so that interested members of the public and scientific community can visit the site during and after site revegetation.

- This Record of Decision (ROD) addresses only the East Foundry Cove Marsh and Constitution Marsh portion of the site. Upon completion of the ongoing remedial investigation/feasibility study for the West Foundry Cove, Hudson River in the vicinity of the Cold Spring pier, and the former battery facility portion of the site, and the completion of the bioassay sampling in East Foundry Cove, a separate ROD will be prepared.

Declarations:

Consistent with the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), and the National Contingency Plan (40 CFR Part 300), I have determined that the selected remedial strategy for the East Foundry Cove Marsh portion of the Marathon Battery Company site is a cost-effective remedy, and that it effectively mitigates and minimizes existing and potential damage to, and provides adequate protection of public health, welfare, and the environment.

The action will require the maintenance of the vegetated marsh to ensure the continued effectiveness of the remedy. The remedy will include thirty years of monitoring of sediment transport and biota, as well.

The Region has consulted with the State of New York in selecting the recommended remedial action for this site. The State concurs that no action, with long-term monitoring, is appropriate for Constitution Marsh, and that dredging is the most appropriate source control measure for the East Foundry Cove Marsh portion of the Marathon Battery Company site.

I have also determined that the action being taken is appropriate when balanced against the availability of Trust Fund monies for use at other sites.

Due to the unavailability of sufficient CERCLA funding at this time, the remedial design will commence after funds become available following reauthorization.

March 3, 1996
Date

Christopher J. Daggett
Regional Administrator

Summary of Remedial Alternative Selection
Marathon Battery Company Site

Site Location and Description:

° Site Location

The Marathon Battery Company site, located in the Village of Cold Spring, Putnam County, New York, approximately 60 kilometers (km) north of New York City, includes the former nickel-cadmium battery manufacturing facility and the surrounding plant grounds, the Hudson River in the vicinity of the Cold Spring pier, and a series of river backwater areas known as Foundry Cove and Constitution Marsh. (See Figures 1 and 2.) Cold Spring has a permanent population of about 2200 residents.

° Site Description

Located on Kemble Avenue, the former battery plant is currently utilized as a book warehouse. A well and pumping station, and a steel water tower are located on the fenced plant property. At the northwestern end of an asphalt parking area lies an underground sealed asphalt and clay lined vault wherein spoils from dredging activities in the Cove are buried. (See Figure 3.) Twenty-nine houses, located on Constitution Avenue, are in the immediate vicinity of the site.

A sanitary sewer line from the plant runs northwards under Kemble Avenue. During the early years of the plant's operation, this sewer line continued westward along Main Street, discharging into the Hudson River at the Cold Spring pier. A New York State Department of Transportation (NYSDOT) storm sewer, and a stormwater/industrial by-pass line running by gravity from the former battery plant, 0.5 km southeastward under Kemble Avenue, discharge into Foundry Cove.

Foundry Cove, a shallow bay and cattail marsh on the east bank of the Hudson River across from West Point, is composed of east and west components. East Foundry Cove is partially isolated from West Foundry Cove and the Hudson River by a railroad bed to the west. The 20 hectare (ha) East Foundry Cove consists of approximately 5 ha of marsh to which the plant's outfall discharged and 15 ha of tidal flat and cove. The exchange of water between East Foundry Cove and West Foundry Cove during flood and ebb tides is through a 10 meter (m) passage under a Metro-North railroad trestle and a channel system which connects Foundry Cove to Constitution Marsh, a 117 ha Audubon Society sanctuary to the south. Located to the north of the site is the residential/business district of Cold Spring. The eastern boundary of the site includes the Old Foundry, a national historic site.

Water depths in West Foundry Cove and the Hudson River in the vicinity of the Cold Spring pier range from 0 to about 6 m, increasing dramatically within several hundred meters of shore. The main channel of the Hudson River in this area averages between 20 and 80 m in depth. The Cold Spring pier area is in an eddy zone created by the pier at the south end of this area and encompasses an area of 110 m taken from the pier. Similiarly, West Foundry Cove is in an eddy area created by Constitution Island. These slow flow eddy areas have a significantly higher deposition of contaminants. Water circulation between Foundry Cove and the Hudson River is mainly influenced by a tide of 1 to 1.5 m, exposing a considerable portion of the East Foundry Cove bottom at low tide. Because of the shallow water depths in the Cove, almost 1/3 of the Cove bottom is covered with aquatic plant growth.

For the purpose of this project, the site is considered as two sub-sites: (1) East Foundry Cove Marsh* and Constitution Marsh and (2) East Foundry Cove, West Foundry Cove, the Hudson River in the vicinity of the Cold Spring pier, and the former battery manufacturing facility. This Record of Decision addresses the first of these sub-sites.

*East Foundry Cove Marsh is defined as including the cattail marsh, outfall area, and the channels in the marsh, as well as the area in East Foundry Cove in the vicinity of the main channel outlet.

Hydrogeology

Putnam County, in the vicinity of the Marathon Battery Company site, is underlain by thin, unconsolidated deposits of mainly glacial origin, resting upon consolidated fractured and faulted bedrock of the Precambrian Age, forming a northeasterly plunging anticline. Bedrock is comprised of Pochuck diorite of igneous origin surrounded by a mass of igneous and metamorphic rocks consisting chiefly of undifferentiated granite and gneiss. The overlying unconsolidated deposits are comprised mainly of till consisting of clay and boulders with some stratified drift deposits of outwash sand and gravel and some silt and clay in the stream valley southeast of Cold Spring. The unconsolidated deposits range in thickness from a few meters to 10 m in the areas surrounding Cold Spring. Soil permeabilities range from $4x10^{-4}$ to $1x10^{-2}$ centimeters per second.

The most important sources of ground water in the area are the consolidated bedrocks. Well yields from these rocks are low (less than 80 liters per minute (1 lpm)), however, and sufficient only to supply domestic, farm and other relatively small needs. The water in the consolidated bedrock is generally under water table conditions in areas where the bedrock out-crops, or where it is covered by relatively permeable unconsolidated deposits. Artesian conditions may occur in both upland and lowland areas where the bedrock is overlain by relatively impermeable glacial till. A storm sewer outfall, constructed by the NYSDOT in the summer of 1984, discharges into East Foundry Cove Marsh, several hundred meters southeast of the Kemble Avenue outfall.

Because of its relative impermeability, the glacial till unconsolidated deposits found in the Cold Spring area constitute a poor ground-water aquifer. The more permeable glacial drift sand and gravel deposits are limited to valleys of the Hudson River and its tributaries. Well yields in these valley deposits average 120 lpm and range as high as 1800 lpm. These sand and gravel deposits are thickest in the Hudson Valley where they are seemingly overlain by a clay and silt layer that may be more than 30 m thick in some places.

In Foundry Cove, loose unconsolidated sediments one meter or less in thickness overlay a hard impermeable clay-like material. (See Figure 4 and Tables 1 and 2.) Ground-water flow in the sediments is toward Foundry Cove or the Hudson River. Flow direction in the deeper fractured rock is dependent on the direction of the fracture systems but is generally toward the river or the cove. On-site, depth to ground water is approximately 6 m.

Several rock wells occur in the vicinity of the site: (1) the former battery facility grounds; (2) Gordon School (3 km to the southeast); (3) Walter Horning home (4 km to the southeast); and (4) Post Road Mobile Home Park (4 km to the northeast).

Topography

The land surface elevation at the former battery plant is about 12 m above mean sea level, sloping towards the south to Foundry Cove and southeast to the marsh. A terrace rises more than 30 m above the land surface to the northeast. Since the land surface at the plant site is currently covered with buildings and pavement, infiltration rates are low and runoff is high. Precipitation in this area is collected by the storm drainage system and discharged to East Foundry Cove Marsh, ultimately discharging into the Hudson River.

Biota

Plant species present in Foundry Cove and Constitution Marsh include emergent types growing in open water such as arrow arum, pickerel weed, and cattail. Water milfoil, a submergent, is found in open water areas. Typha and arrow arum are the predominant plant species existing in the outfall area. An unusual cattail morphology of the lower portion of the inflorescence was observed near the Kemble Avenue outfall (Acres, 1985).

The predominant faunal population observed in and around the Foundry Cove and Constitution Marsh area include mice, Norway rats, muskrat, snapping turtles, catfish, banded killifish, sunfish, carp, white perch, eel, pickerel frogs, and blue crabs. The dominant benthic organisms are chironomid larvae (Diptera) and oligochaete (segmented) worms. Migrating waterfowl, predominantly ducks and geese, are periodically present, as well (Acres, 1985).

Historic Sites

A considerable number of historic areas are in the vicinity of the site, including the Cold Spring Historic District, composed of 31 properties of Main Street; the West Point Foundry Historic District, covering all of East Foundry Cove and a portion of the Foundry Brook drainage basin; the Fair Lawn area, orginating near the mouth of Foundry Brook and contiguous to the West Point Foundry area; the Boscobel Historical site, located adjacent to Constitution Marsh; and Eagle's Rest Historic Area, including much of the southern portion of Foundry Cove.

Site History:

In 1952, the U.S. Army Corps of Engineers constructed a battery manufacturing facility in the Village of Cold Spring, Putnam County, New York, for the U.S. Army Signal Supply Agency (REI, 1983).

In 1953, under contract with the Army Signal Corps, Sonotone Corporation began operating the plant to produce nickel-cadmium batteries for use in the NIKE Missile Program. Subsequent contracts for battery production at the plant included batteries for warhead failsafe systems and military jet fighter batteries. Between 1954 and 1955, the contract was amended to permit Sonotone Corporation to produce commercial batteries (REI, 1983).

In 1962, the government, having declared the property excess, sold it to Sonotone Corporation. In 1967, Sonotone Corporation became a wholly-owned subsidiary of Clevite Corporation. In 1969, Clevite Corporation merged with Gould, Incorporated. In 1969, Gould, Incorporated sold the plant to Business Fund, Incorporated which later changed its name to Marathon Battery Company. Marathon Battery Company operated the plant until March 1979. The plant was inactive from March 1979 until November 1980, when it was sold to the current owner, Merchandise Dynamics, Incorporated, for use as a book storage facility. Prior to selling the plant to Merchandise Dynamics, Incorporated, all battery manufacturing equipment was removed and shipped to a Marathon Battery Company plant in Waco, Texas, and approximately 225,000 kg of drummed process wastes were shipped to Precious Metals Refining Corporation in Hollywood, California for refining and recycling (REI, 1983).

The plant's original wastewater treatment system consisted of a lift station and piping for transfer of all process wastewater into the Cold Spring sewer system for discharge directly into the Hudson River. In addition, a by-pass valve was installed so that when the lift station was shut down or overloaded, a direct gravity discharge could be made into a storm sewer for discharge into East Foundry Cove Marsh. By-passes into this storm sewer system were frequently necessary because the high dissolved solids and pH of the effluent resulted in extreme fouling within the pump and piping, as well as erosion of the pump and impeller case. As the capacity of the pump was reduced by these effects, the pump could not handle the wastewater flow, and ultimately, the pumps required shut down and maintenance or replacement. To accommodate peak flows, and during pump maintenance, the by-pass valve was opened and the flow diverted to East Foundry Cove Marsh. This occurred at least twice weekly for periods of time ranging from a few hours to a full operating shift. Calculations by consultants for Marathon Battery Company have indicated that approximately 50,000 kg of cadmium may have been discharged to the Cove during the life of the plant (REI, 1983).

During 1965, the New York State Department of Health (NYSDOH) identified the need for a sewage treatment plant in the Village of Cold Spring. During the design of the sewage treatment facility, the Village's consultant concluded that the battery plant's process effluent could not be managed by the proposed sewage treatment system. Subsequently, the Village of Cold Spring ordered Sonotone Corporation to disconnect its industrial discharge from the Village's sanitary sewer. To accomplish this directive, Sonotone shut down the diversion pumps and by-passed the entire wastewater flow into the storm sewer to East Foundry Cove Marsh. Sonotone then installed equipment which was designed to precipitate metal hydroxides and adjust the pH of the wastewater prior to discharge into the storm sewer system. This treatment system, however, failed to operate properly. As a result, the treated wastewater failed to meet state discharge regulations, and

the plant was given a January 1, 1970 deadline to achieve compliance with discharge regulations (REI, 1983).

Pursuant to the final judgment in 70 Civ. 4110, discussed in the Enforcement section, hydraulic dredging was conducted between September 1972 and July 1973. Figure 5 illustrates the extent of the dredging operation. The outfall area was dredged to a depth of 0.6 m at which point a solid clay-gravel base was encountered. The base, found to be relatively contaminant free, was not removed. The channel was dredged to a depth varying from 0.6-1.2 m and 90,000 square meters (m^2), 0.3 m deep area was removed from the main body of the Cove. All dredge spoils were deposited in a diked enclosure constructed over a parking lot on the battery facility property. Approximately 4,000 cubic meters (m^3) of material were eventually retained. During the dewatering process, the sediments were allowed to settle overnight. The next morning, the supernatant passed through a storm drain and back into Foundry Cove (Gregor, 1973).

After completion of the dredging operation, the dewatered dredge spoils, were placed in a clay-lined underground vault on the plant property. The vault was then sealed with asphalt and fenced.

Various studies by New York University (NYU) and others were conducted on the Foundry Cove cadmium contamination problem prior to, during, and after the dredging activities. Post-dredging monitoring continued to detect elevated cadmium and nickel concentrations in the Cove's sediments, flora, and fauna.

In October 1981, EPA listed the Marathon Battery Company site on the National Priorities List.

In August 1983, EPA and the State of New York signed a cooperative agreement to undertake a remedial investigation and feasibility study (RI/FS) for the Marathon Battery Company site. ACRES International, the New York State Department of Environmental Conservation consultant, initiated the RI/FS covered by the cooperative agreement in May 1984.

An RI report on the nature and extent of the contamination of the Foundry Cove/Hudson River portion of the site was completed in July 1985. A draft FS for this portion of this site was completed in August 1985. Because the FS contained insufficient information to evaluate effectively the technical merits and environmental effects of the remedial alternatives under consideration, the U.S. Army Corps of Engineers (COE) was tasked to expand upon the study by further evaluating technically feasible means of remediating Foundry Cove and Constitution Marsh, including identifying and evaluating effective means of containing the site's cadmium-contaminated sediments, evaluating the effectiveness and efficiencies of site-wide and hot spot dredging, and determining the long-term hydraulic impacts on Constitution Marsh associated with dredging and/or containing the contaminated sediments in Foundry Cove. The COE completed its technical assistance in February 1986. In addition, some additional RI/FS activities were performed by EPA Zone Contractor, EBASCO Services, Incorporated. These activities included: bench top testing of heavy metal treatment technologies; additional sediment corings in Constitution Marsh; a wetland assessment, and interpretation and incorporation of the COE's technical assistance input, and the results of the bench top testing, sediment corings, and wetland assessment, into a supplemental RI/FS. This work was completed in August 1986.

Current Site Status:

Sediments and surface water are the two potential routes of exposure associated with the East Foundry Cove Marsh/Constitution Marsh portion of the Marathon Battery Company site.

° Sediments

Assessment of the sediments focused on identifying the degree of sediment contamination in terms of location and depth.

Tables 3 and 4 summarize the cadmium, cobalt and nickel concentrations detected in the sediments of each of the areas sampled. Figures 6, 7, and 8 illustrate the mean sediment concentration for each of these areas. The areal extent of the cadmium contamination in East Foundry Cove Marsh and Constitution Marsh are illustrated on Figure 9. Metals contamination in the sediments displayed very perceptible patterns, reflecting the original point source discharge of the cadmium, nickel, and cobalt into Foundry Cove, their subsequent transport, and their gradually decreasing levels at sites progressing away from the discharge point. In general, the data show that sediments of East Foundry Cove Marsh and the northern proximity of Constitution Marsh are contaminated relative to Tivoli Bay, the control site, (Acres, 1985 and Ebasco RI, 1986).

The highest level of contamination occurs in East Foundry Cove Marsh in close proximity to the Kemble Avenue outfall. This area is characterized by a layer of greenish-white sediment spanning an approximately 15 by 30 m area. Contaminant concentrations in the East Foundry Cove Marsh outfall area were as high as 171,000, 156,000, and 6,700 mg/kg for cadmium, nickel, and cobalt, respectively, to depths greater than 50 cm (Acres, 1983).

Sediment contamination radiates away from the East Foundry Cove Marsh outfall along a pattern that follows the channel connecting East Foundry Cove Marsh to the main body of East Foundry Cove. Levels of cadmium in the surficial sediments of this channel and at its mouth range between 1,000-10,000+ mg/kg. Overall, the cadmium concentration measured in the sediment decreased by four orders of magnitude at increased distances from the outfall (Bower, 1978).

Southeast of the channel mouth is an area in East Foundry Cove Marsh approximately 75 by 15 m containing increased levels of cadmium up to 40,000 mg/kg. The distribution of the cadmium in this area, as well as within the remainder of East Foundry Cove appears to be dictated by: (1) the tendency of the flooding tidal patterns, bringing water in from the Hudson River and West Foundry Cove, to follow the north shore; (2) the tendency of the ebbing tidal patterns, removing water and any associated contaminants from East Foundry Cove, to follow the south shore; (3) the 1972-1973 dredging effort along the north shore of the marsh; and (4) the presence of aquatic vegetation in shallower areas which contribute to deposition in these areas (Acres, 1985).

The northwestern shore contains cadmium concentrations which approach background levels* at all depths. Sites investigated along the south shore displayed surficial cadmium at concentrations in the 100-500 mg/kg range. At depth, background levels are observed. The central portion of East Foundry Cove, which is generally shallower and tends to be dominated by rooted emergent vegetation during the summer months, exhibited surficial cadmium concentrations of 500-1,000 mg/kg. Contamination at depth does not exist at this location, either (Acres, 1985).

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* Background cadmium concentrations in the Hudson River Estuary has shown wide special variability ranging from 1.94 mg/kg to 14.1 mg/kg (Kneip and O'Connor 1979, and O'Connor and Moese, 1984) with a mean concentration of approximately 10 mg/kg.

As can be seen by Table 4, in Constitution Marsh contamination is present in the surficial sediments of the main channels in the northern section of the marsh, with 40% of the marsh sediments showing cadmium and nickel concentrations greater than 100 mg/kg to 10 cm deep. Overall, levels of cadmium range from 4.0 to 940 mg/kg, nickel concentrations range from 9 to 1600 mg/kg, cobalt concentrations range from 4 to 99 mg/kg (Acres, 1985 and Ebasco RI, 1986).

In the southern channels of Constitution Marsh, surficial cadmium concentrations are statistically significant when compared to the control site, but are much reduced from the levels observed in the northern channels of the marsh. The nature of the tidal patterns in the marsh, which originate from the eastern and southern portions of Foundry Cove and meet at the middle of the marsh, appear to limit the opportunity for contaminant transport to the southern reaches of the marsh. Subsurface strata at all stations reflect background conditions (Acres, 1985).

No federal or state standards or criteria have been established for cadmium, nickel, or cobalt in sediments. Therefore, after careful analysis of scientific research, prior investigative work at the site, and the previous dredging of the outfall and channel to 900 mg/kg, 100 mg/kg was selected for remediation of the site. (See Alternatives Evaluation section for further discussion of the selection of this action level.)

Surface Water

Equilibrium chemistry studies of cadmium and nickel, have shown nickel to be more mobile than cadmium (Bondietti et. al., 1974). Cadmium tends to be associated with carbonates whereas nickel is usually associated with iron and manganese oxides, but the presence of ligands and organic material can affect these associations (Moore and Ramamoorthy, 1984). Both metals have been shown to be readily adsorbed by plant detritus (Odum and Drifmeyer, 1978). In addition, salinity and pH can exert strong effects on the equilibrium chemistry of cadmium and nickel (Hazen and Kneip, 1976).

Figures 10, 11, and 12 illustrate the total and soluble cadmium, cobalt, and nickel concentrations in the surface water. Since the cadmium is in a form that is highly available in East Foundry Cove Marsh (Sloan, 1986), cadmium levels in East Foundry Cove as high as 0.27 mg/l have been detected. At some East Foundry Cove stations, EPA water quality criteria for protection of freshwater aquatic life from toxic conditions have been exceeded. These standards for total cadmium water concentrations are 6.6×10^{-4} to 2.0×10^{-3} mg/l for water hardness levels of 50 and 200 mg/l, respectively. (Levels of hardness present at the site range from 100-150 mg/l.)

The elevated levels of cadmium in East Foundry Cove on an ebb tide versus a flood tide indicate that tidal resuspension and transport of sediments is occurring (Acres, 1985). (See Table 5.) It appears that under normal hydrologic events, however, the extent of this transfer is minimal.

Based on the federal nickel water quality criteria for the protection of aquatic life, the levels of nickel found will not harm the aquatic biota. No standards or criteria have been established for cobalt.

The sewer system which carried the industrial wastes to East Foundry Cove Marsh does not appear to be a continuing source of contamination. No sediment was found in the section of the Kemble Avenue line downgradient of the former battery plant. It appears that flushing or scouring as a result of storm flow maintains the accessible portion of the Kemble Avenue line relatively free of accumulated sediments. In addition, this line was hydraulically flushed in the early 1970s during the dredging of the outfall area (Acres, 1985).

A volatile organic scan failed to detect the presence of any volatile organic acids for any water or sediment samples. Organic priority pollutant analysis of sediments collected show the presence of some base/neutral compounds. None of the detected contaminants were chlorinated. The base/neutrals measured in appreciable quantities are typically associated with runoff from paved areas. Although elevated in relation to the other sampled areas, the observed concentrations are not excessively high. (See Table 6.)

A number of hydrological phenomena associated with observed flow patterns and tides appear to be responsible for the distribution of contaminants in East Foundry Cove. Sediment analysis confirms that there has been transport of cadmium, nickel, and cobalt away from the site of deposition, resulting in contamination of peripheral areas. The data further show that the degree of contamination radiates from the East Foundry Cove Marsh outfall area, such that those sites progressively distant from the outfall are less contaminated. The pattern of contamination in Foundry Cove is very similar to the patterns of hydrodynamic flow. High energy areas tend to be less contaminated than those sites where the settling of particulates is enhanced as a result of low velocities and dense stands of aquatic macrophytes. Contaminants in Foundry Cove are being redistributed and are now present over a wider area and at greater depths than documented in 1972-1976 by Kneip. Tidal action redistribution of cadmium from contaminated undredged areas may have influenced existing patterns of contamination (Acres, 1985 and Ebasco RI, 1986).

Daily tidal fluctuations and the resulting current velocities, periodically combined with significant runoff in flow from the Kemble Avenue and NYSDOT outfalls, account for the primary short-term sediment transport mechanism. The relative movement of sediment is dependent on the tidal stage fluctuation magnitude and the resulting strength of the ebb and flood currents. Some of the recontamination might also be the result of marsh bank erosion and the subsequent filling of the channel. The discharge of waters back into Foundry Cove during the initial dredge spoil dewatering operations may have also reintroduced contaminated sediments to the cove (Acres, 1985).

Constitution Marsh is influenced by the flow of water from both East Foundry Cove and South Cove. The hydrodynamics of tidal flux in Constitution Marsh is such that those stations which are primarily subjected to water movement from East Foundry Cove display a higher degree of metal contamination than those influenced by South Cove tidal activities. The transport of contaminated material into South Cove appears limited (Acres, 1985).

Biota Contamination

The degree of the cadmium contamination present in the biota in the Foundry Cove area is a clear indication of the environmental threat posed by the site.

Practically every trophic group sampled had elevated tissue burdens of cadmium. Those organisms and plant samples from the outfall area typically displayed elevated cobalt and nickel concentrations as well. Those species in direct contact with the contaminated substrate, including benthos, terrestial oligochaetes, and wetland vegetation, or those species with an extended duration of exposure, including macroinvertebrates, fish, wood ducks, and mammals, display the greatest amount of metal accumulation (Acres, 1985). (See Figures 13-20.)

The wetland vegetation in the East Foundry Cove Marsh outfall area is highly contaminated, with average cadmium, nickel, and cobalt concentrations in the roots of 500, 250, and 10 ug/l, respectively. Significant levels of heavy metals contamination also occur in Constitution Marsh. The presence of excessive cadmium in the tissues of these plants, particularly Typha, is ecologically significant. Vegetation serves an important role in the trophic pathways of the marsh ecosystem. Incorporation of metals in the tissues of the vegetation may lead to bioaccumulation in mammals (Erickson, 1983) and waterfowl (DiGiulio, 1982). Acting as an environmental sink, the detritus becomes incorporated in the sediment and provides a medium for bacteria and a food source for the benthic infauna (Acres, 1985).

Infrared aerial photographs were examined for evidence of potential vegetation community stress. Although particular attention was paid to sections of the marsh where elevated sediment contaminant levels had been documented, no obvious patterns of stressed vegetation were revealed (Acres, 1985).

No significant relationship between benthic infaunal community structures and metal contamination levels in the sediment has been found. With the possible exception of variation in community patterns within Foundry Cove, the variation in abundances and diversity of the benthic in faunal community may relate to diversity in the forms of contamination present and the alterations which occur with changes in hardness, pH, salinity, and other variables (Sloan, 1986).

Organisms which are part of the detrital food web such as fish, macroinvertebrates, and some wading birds and waterfowl may uptake the contaminants through ingestion. Table 7 shows the levels of contamination in benthic infauna and the corresponding sediment concentrations. The highest cadmium concentration, 570 ug/l, found in the infauna in the vicinity of the East Foundry Cove Marsh outfall, corresponds to 5,100 ug/l in the sediment. A benthic algae sample in this area showed concentration of 2,840 ug/l, 2,200 ug/l, and 120 ug/l for cadmium, nickel, and cobalt, respectively. Cadmium levels in Foundry Cove phytoplankton and zooplankton were as high as 540 ug/g and 870 ug/g, respectively. (Acres, 1985) (See Table 8.)

The data indicate that fish from the Foundry Cove/Constitution Marsh area have elevated levels of tissue contamination. The occurrence of elevated levels of cadmium in certain tissues of Morone americana (white perch) is noteworthy. Although the flesh was found to be contaminated at levels equal to or below 0.32 ug/g, liver concentrations as high as 47 ug/g were detected. (See Table 9.) It is difficult to conclude that this contamination is solely the result of exposure to Foundry Cove, as fish are highly mobile. The bioaccumulation study revealed, however, that significant body tissue uptake of cadmium occurs even under a limited duration of exposure (Acres, 1985).

Cadmium contamination of the macroinvertibrates (blue crab) is recognized as a widescale problem in the Hudson River (Axelrod and Flacke, 1981). Foundry Cove has been identified as one of the more important sources of such contamination (Kuzia, 1981). The bioaccumulation study conducted by Acres documented a rapid and significant accumulation of cadmium in the tissues of crustaceans (crayfish) even over a limited period of exposure. Although the blue crab remains in the Foundry Cove area for only a short time, it appears to be susceptible to cadmium accumulation during this brief exposure. Table 10 shows an average concentration of 19.4 ug/g hepatic cadmium in East Foundry Cove blue crab samples.

Cadmium levels in reptiles (snapping turtles) from Foundry Cove and Constitution Marsh were elevated for kidneys and liver at 27 ug/g and 23 ug/g, respectively. (See Table 10.) Some of the turtles examined were found to have liver or kidney abnormalities, suggesting sub-lethal effects related to the elevated levels of cadmium. The muscle tissue of the snapping turtles, however, did not exhibit contaminant levels any higher than those from Tivoli Bay (Acres, 1985).

The mammals, as represented by mice, rats, and muskrats contained significant levels of cadmium in specimens from Foundry Cove. It is suspected that the muskrat population of Foundry Cove/Constitution Marsh have experienced limited reproductive success. Lodges, built in early spring, have been found abandoned and lacking kits. The consumption of

cadmium-contaminated Typha, an important forage item of muskrats, leads to the accumulation of the metal in the muskrats and may elicit sub-lethal impacts such as reproductive failure (Rod, 1986).

The rats and mice examined from Foundry Cove and the adjacent upland areas, displayed elevated cadmium contamination with levels in one rat reaching 270 ug/g in the liver and 210 ug/g in the kidney. (See Table 10.) Some of the livers examined were found to be discolored and four contained necrotic spots. The necrotic spots were determined to be related to stress resulting from the cadmium contamination (Sloan, 1986).

Crab samples taken from downriver locations were also found to be contaminated with cadmium. This contamination may not be directly attributable to East Foundry Cove contamination, since cadmium contamination is a widespread problem in the Hudson River, and a significant quantity of cadmium was discharged to the Hudson River at the Pier site.

Total cadmium concentrations in water greater than 7-10 ug/l have been observed to reduce hatchability of eggs, increase larval fish mortalities, and decrease standing crop size (USEPA, 1979; Eaton, 1974; Eisler, 1971). Zooplankton, particularly the sensitive forms such as cladocerans, have been demonstrated to be significantly affected by dissolved cadmium concentrations of 0.7 to 3.4 ug/l (Anderson, et. al. 1975). Thus, some of the observed concentrations of cadmium detected at the site may be sufficient to impact substantially aquatic life.

As can be seen by the data, cadmium contamination is evident in all trophic levels and is being bioaccumulated through the food chain. Figure 21 shows that aquatic organisms exposed

to the Foundry Cove area for as little as seven days substantially increase their tissue levels of cadmium (Acres, 1985). Consequently, transient species of fish and blue crab which venture into the Foundry Cove area for short periods of time may experience similar cadmium contamination. Levinton has shown that genetic selection is occurring as a result of the cadmium contamination and that organisms transplanted from South Cove will not survive in East Foundry Cove (Sloan, 1986). To date, however, the only acute effects of the high sediment concentrations have been shown by Kneip (1980) to be a decrease in diversity and abundance of the benthic community where sediment concentrations were greater than 10,000 mg/kg cadmium in East Foundry Cove Marsh. Muskrats, however, are having a difficult time surviving in East Foundry Cove as compared to Constitution Marsh (Sloan, 1986).

Generally, Constitution Marsh is considered to be healthy based on observations by many researchers who have worked at this site but have been unable to find any major ecosystem-wide impact which could have resulted from a stressed environment. Because of the rarity of extensive cattail stands, Constitution Marsh may represent an important component of the larger Hudson River Estuary. The habitat it provides for nesting least bittern and wood duck, and migrating waterfowl and raptor is of regional importance (Acres, 1985 and Ebasco RI, 1986).

The contribution of the site's wetlands in the support of the Hudson Estuaries Fishery Resources is not known. Many fish species reside in or temporarily enter the wetlands for feeding and/or spawning. In addition, the contribution of marsh invertebrates to the Hudson River food web has not been extensively studied. Generally, estuarine invertebrate are an important link between detritus, algae, fish, birds, reptiles, and mammals.

Nickel has been found to be less toxic than cadmium. Susceptibility to nickel toxicity in aquatic plants is for the most part, species-dependent. The nickel uptake rate increases with exposure concentration, and much of the metal is bound internally. Significant aquatic plant growth and photosynthesis reductions generally have been found to occur at water concentrations of 0.1-0.5 mg/l (Moore and Ramamoorthy, 1984). The International Agency for Research on Cancer lists nickel and its soluble forms as animal positive carcinogens (Sittig, 1981).

Cobalt concentration of 0.04 mg/l in water have been found to retard algal growth (Coleman, et. al, 1971).

* Human Health

Although cadmium concentrations in the typically ingested tissues of edible species of fish and crab do not indicate an immediate public health hazard, levels in liver and kidney tissues are sufficiently high to warrant attention to the potential for such a risk to humans.

Cadmium has no known beneficial or essential role in human health. Typically, approximately 5-6 percent of the cadmium entering the gastrointestinal tract is absorbed. After absorption, the blood transports cadmium throughout the body. The liver takes up the cadmium where it is incorporated into a metal-binding protein. The protein-bound cadmium is then released back into the blood and is deposited into the kidneys and other soft tissues, including the testes, lungs, pancreas, spleen, and various endocrine organs. This binding and deposition process is believed to be responsible for cadmium's long half-life (16-33 years (WHO, 1972)) in the the human body (USEPA, 1981). Renal dysfunction is the most typical and severe effect of chronic low-level cadmium exposure. Cadmium is also a potential carcinogen (Sittig, 1981).

Based upon a survey of crab consumption by the residents of Cold Spring, the New York University Medical Center determined that a potentially serious chronic health hazard to some portion of the crab-eating population does exist (Kneip et. al., 1979). Using extrapolated data from juvenile and adult crabs, it was estimated by Kneip that crab consumption by some Cold Spring residents at the present level could lead to critical kidney damage in 12.5 to 50 years. The New York State Commissioner of Health, on April 21, 1977, issued a health advisory that crabs from Foundry Cove not be consumed. Wiedow (1981) indicated a possible widespread problem as crabs taken from other areas of the Hudson River had elevated cadmium levels, as well (5-40 ug cadmium per gram wet weight in the hepatopancreas). Therefore, an expansion of the previous warning was made in the spring of 1981, advising the public to eat not more than one meal a week of crabs taken from the Hudson River.

In terms of the degree of the threat to human health, nickel is less toxic than cadmium. Local exposure to nickel irritates the nose, eyes, mouth, throat, skin, and various parts of the respiratory and gastrointestinal systems. Absorption, however, does not occur (Sittig, 1981).

Ingestion or inhalation of high concentrations of cobalt generally results in vomiting, diarrhea, and a sensation of "hotness" (Sittig, 1981).

Based upon the results of a probalistic human health impact assessment prepared by Ebasco, the following conclusions were drawn:

1. Components of the biota of Foundry Cove are contaminated with cadmium to the extent that large indiscrete individual consumption of certain species presents a human health risk.

2. The area of greatest human health concern is East Foundry Cove Marsh where significant levels of cadmium contamination have been found in the sediments. Constitution Marsh contamination presents a minor health impact.

3. Consumption of aquatic biota was identified as the most probable means of human exposure to site contaminants. Concentrations of cadmium less than 900 mg/kg in East Foundry Cove Marsh and Constitution Marsh sediments will pose no human health-related threats through the consumption of aquatic biota.

4. Direct contact and ingestion of suspended contaminated sediment during recreational uses of this area, such as swimming, boating, and nature observation, are pathways of little importance.

To alleviate the environmental and potential human health effects stemming from the excessive levels of heavy metals contamination found in the East Foundry Cove Marsh sediments, and to prevent further migration of these highly contaminated sediments to Foundry Cove, the Hudson River, and Constitution Marsh, remedial action is called for.

Enforcement:

On September 22, 1970, a complaint was filed (70 Civ. 4110) in the U.S. District Court, Southern District of New York, by the United States against Marathon Battery Company for violation of Sections 407, 413, and 441 of Title 33 of the United States Code ("Refuse Act"). The complaint sought preliminary and permanent injunctive relief, enjoining and restraining the "discharge or deposit of any alkali, or any salt of nickel, cadmium or cobalt... directly or indirectly into Foundry Cove or the Hudson River..." and ordering Marathon Battery Company to remove promptly the "deposited salts, and any other refuse or debris deposited in Foundry Cove." The complaint was amended in the course of the following year, and defendants filed their answers. Sonotone Corporation, Gould, Incorporated, Clevite Corporation, the State of New York, and Old Foundry Realty Corporation had been joined as defendants. Subsequently, the suit was settled out of court.

A final judgment, entered on June 8, 1972, required the removal of contaminated sediments to a concentration of 900 milligrams per kilogram (mg/kg) from the outfall area adjacent to the discharge pipe, the channel leading to the main body of Foundry Cove, and a portion of the Cove. Marathon Battery Company, Sonotone Corporation, Clevite Corporation, and Gould, Incorporated participated in the limited cleanup of Foundry Cove.

In response to a report filed with the court on behalf of the defendants, the United States filed a satisfaction of judgment, stating that "the defendants...are deemed to have complied with the terms of the final judgment, as amended, with respect to the removal of the deposits of cadmium from Foundry Cove and are relieved from any further obligation with respect thereto." (REI, 1983).

The Army was not named a co-defendant in the U.S. Attorney's original suit. Marathon Battery Company, Sonotone Corporation, Clevite Corporation, and Gould, Incorporated alleged that the Army had participated in damaging Foundry Cove by engineering and approving the plant design and by constructing the plant. Therefore, they claimed the Army should be liable for damages. The Army was not required to join in the suit, and, since the case was settled out of court, the judge never ruled on the question of Army responsibility (Putnam, Hayes, & Bartlett, 1983).

EPA intends to proceed under CERCLA against the Potentially Responsible Parties (PRPs). Consequently notice letters were sent to U.S. Army, Marathon Battery Company, Gould, Incorporated, Sonotone International, and Imperial Clevite, as well as to Merchandise Dynamics, Incorporated, the current property owner.

Marathon Battery Company, Gould, Incorporated and the COE have cooperated in supplying information and meeting with the Agency. Marathon Battery Company has provided estimates of metallic contaminant discharges into Foundry Cove which occurred during each year of operation throughout the life of the plant. Marathon Battery Company and Gould, Incorporated have commented on the RI and FS documents. From an archival search, the COE has prepared a summary of the history of the site and the associated threat.

It is EPA's intention to negotiate with the PRPs for the implementation of the remedy. If these negotiations are fruitless, EPA will pursue all its legal options under CERCLA.

Alternatives Evaluation:

The primary objective of the feasibility study was to evaluate remedial alternatives using a cost-effective approach consistent with the goals and objectives of CERCLA. According to 40 CFR 300.68(i), the appropriate extent of a remedy will be based upon the selection of a cost-effective remedial alternative which effectively mitigates and minimizes damage to and provides adequate protection of the public health, welfare, or the environment. The NCP outlines procedures and criteria to be used in selecting the most cost-effective alternative.

The first step is to evaluate public health and environmental effects and welfare concerns associated with the problem. Criteria to be considered are outlined in Section 300.68(e) of the NCP and include such factors as actual or potential direct contact with hazardous material, degree of contamination of drinking water, and extent of isolation and/or migration of the contaminant.

The next step is to develop a limited list of possible remedial alternatives which could be implemented. The no-action alternative may be included on the list.

The third step in the process is to provide an initial screening of the remaining alternatives. The costs, relative effectiveness in minimizing threats, and engineering feasibility are reviewed here. The no-action alternative may be included for further evaluation when response actions may cause greater environmental or health damage than no-action responses. A no-action alternative may also be included if it is appropriate relative to the extent of the existing threat or if response actions provide no greater protection. From the evaluation of existing data and information on the nature and extent of the contamination associated with the East Foundry Cove Marsh/Constitution Marsh portion of Marathon Battery Company site, the following remedial objectives were established:

- Prevention of all biota from contacting East Foundry Cove Marsh and Constitution Marsh contaminated sediments that would threaten them;

- Prevention of resuspension and redistribution of the contaminated sediments that would threaten the area flora and fauna; and

- Minimization of the disturbance to Constitution Marsh, since this wetland is a delicate ecological habitat.

In the absence of standards or criteria for contaminant levels of cadmium, nickel, and cobalt in sediments, to evaluate remedial alternatives for East Foundry Cove Marsh and Constitution Marsh, it was necessary to establish an acceptable cadmium contaminant level for the site.

Based upon Ebasco's probalistic human health impact assessment, 900 mg/kg was found to be an acceptable cadmium concentration level to protect public health. Information of a similar nature pertaining to the protection of the environment, however, was not available, although sediment concentrations

ranging from 10 mg/kg (background) to 900 mg/kg cadmium have been suggested for remediation action levels for the site.

McNaughton (1974) observed reduced growth of broad-leaf cattails grown in soils with 73 mg/kg cadmium relative to plants grown on soils with approximately 2 mg/kg cadmium.

Research performed for EPA (JRB, 1984) established sediment criteria for cadmium based upon limiting concentrations in water to levels below EPA Ambient Water Quality Criteria. Although this technique has not been thoroughly tested at this time, preliminary results have shown that sediment cadmium toxicity decreases with increasing organic content: for a total organic carbon (TOC) concentration of 5%, the chronic sediment cadmium criterion was found to be 38.5 mg/kg, and at a TOC of 10%, the chronic level was found to be 77 mg/kg. Ebasco's field results showing an average TOC value of 7% for this area (See Table 7) would imply that a cadmium concentration somewhere in the range of 60 mg/kg would be required to prevent chronic exposure. The proportion of cadmium found in the sediment to that in aqueous solution in the marsh, however, will depend not only on TOC, but on other site-specific factors including water chemistry, pH, oxidation/reduction potential, and temperature. Therefore, the model for partitioning based on simplifying assumptions will only approximate site-specific cadmium criterion (ERT, 1986).

Based upon an analysis of available information and the above-referenced research, as well as discussions with state and federal fish and wildlife experts, a site-specific sediment cadmium remediation level of 100 mg/kg was established.

Based upon the analyses described above, remediation to background would be unnecessarily overprotective. Remediation to 900 mg/kg, on the other hand, would not be adequate to protect against the threat to the environment posed by the site. (It should be noted that the previous dredging operation to 900 mg/kg was unsuccessful.)

No action level was established for nickel and cobalt since it was assumed that any remedial action undertaken would mitigate cobalt and nickel contaminant levels, as well.

With the stated objectives and response criteria in mind, an extensive list of feasible remedial technolgies was developed. (See Table 11.) Due to the complex environmental, technical, regulatory and health issues associated with this site, the number of technologies and possible combinations was considerable, necessitating a phased evaluation process.

In order to evaluate the applicability and suitability of potential remedial treatment technologies, bench scale feasibility tests were performed. These tests generated empirical data on the performance of various technologies for transport or treatment. The results from these bench-scale tests showed that: (1) most of the contaminant metals found in the dredging water are bound to the resuspended solids and only trace concentrations of the metals will leach out in the dissolved phase; (2) dredging water will require treatment to meet NYSDEC suspended solids and total metal standards; (3) acid leaching of the sediments to remove significant quantities of the contaminant metals is not an effective remedial technology; (4) hydraulically dredged sediment can be sufficiently thickened by settling, and can be efficiently dewatered by filtration without adding conditioning agents; and (5) the contaminant metals can be chemically fixated in the sediments and the fixated sediments will pass the Resource Conservation and Recovery Act (RCRA) EP Toxicity Test to be classified as non-hazardous.

A feasibility screening eliminated those remedial technologies that were not technically applicable or effective because of site conditions. Table 12 summarizes the results of the feasibility screening of technologies.

The remedial technologies surviving the feasibility screening were combined into five remedial alternatives:

I. No Action
II. Hydraulic Dredging/Thickening/Fixation/Off-Site Disposal
III. Hydraulic Dredging/Thickening/Fixation/On-Site Disposal
IV. Hydraulic Dredging/Thickening/Dewatering/Off-Site Disposal
V. Containment

Considering the different degrees of contamination leading to varying degrees of public health and environmental risk, and considering the differing physical conditions between East Foundry Cove Marsh and Constitution Marsh, the alternatives were screened in terms of the two sub-sites: East Foundry Cove Marsh (ECM), and Constitution Marsh (CM). The purposes of this subdivision were to allow consideration of different remedial technologies/alternatives for both areas and to provide the flexibility in decision-making to select the most cost-effective remedial alternative for both areas.

Based on these considerations, the potential remedial alternatives identified for the two sub-sites are as follows:

East Foundry Cove Marsh (ECM)

- °Alternative ECM-1: No Action
- °Alternative ECM-2: Hydraulic Dredging/Thickening/Fixation/Off-site Disposal
- °Alternative ECM-3: Hydraulic Dredging/Thickening/Fixation/On-site Disposal
- °Alternative ECM-4: Hydraulic Dredging/Thickening/Dewatering/Off-site Disposal
- °Alternative ECM-5: Containment

Constitution Marsh (CM)

- Alternative CM-1: No Action
- Alternative CM-2: Hydraulic Dredging/Thickening/Fixation/Off-Site Disposal
- Alternative CM-3: Hydraulic Dredging/Thickening/Dewatering/Off-Site Disposal
- Alternative CM-4: Hydraulic Dredging/Thickening/Fixation/On-Site Disposal
- Alternative CM-5: Containment

These alternatives were subjected to a secondary screening with the objective of identifying those alternatives with sufficient merit to undergo detailed evaluation. The emphasis in the secondary screening was on the technical feasibility, environmental effects, and order-of-magnitude costs.

Based upon the secondary screening of these remedial alternatives, Constitution Marsh Alternative CM-4, hydraulic dredging thickening/fixation/on-site disposal, and Alternative CM-5, containment, were deleted from further consideration. Alternative CM-4 would require the dredging of a significant volume of sediments. This alternative was deleted from further consideration because, due to limited land availability, a 7 ha on-site disposal site is not feasible. Because of the significant environmental impacts associated with capping a 40 ha wetland, Alternative CM-5 was deleted from further consideration.

The remaining alternatives were then evaluated in terms of technical feasibility, environmental considerations, institutional considerations, public health considerations, and cost.

The NCP requires that at least one remedial alternative should be considered for each of the five categories listed below:

1) A no-action alternative.

2) Alternatives which attain applicable or relevant and appropriate (ARAR) federal public health or environmental standards.

3) Alternatives which exceed ARAR federal public health or environmental standards.

4) Alternatives for treatment or disposal at an approved off-site facility.

5) Alternatives which do not attain applicable or relevant federal public health or environmental standards, but will reduce the likelihood of present or future threat from hazardous substances.

Table 13 summarizes the status of each of the alternatives considered with regard to these five categories.

According to the NCP, a total cost estimate must also be considered for remedial actions and must include both construction and annual operation and maintenance costs. These costs are estimated for the alternatives under consideration. A present worth value analysis was used to convert the annual operation and maintenance costs to an equivalent single value. These costs were considered over a thirty year period at a ten percent discount rate.

I. NO ACTION:

Alternative ECM-1

The no-action alternative for East Foundry Cove Marsh would involve restricting access to the site and minimization of resuspension of the sediments as much as possible. This alternative would include a 2.5 m high, 490 m long security fence that would be installed on the north edge of the marsh to restrict public access. A 600 m long permanent silt curtain would be constructed along the south edge of the marsh to restrict sediment migration into East Foundry Cove.

The Kemble Avenue storm sewer and the NYSDOT storm sewer would be diverted by constructing two diversion ditches along the north edge of East Foundry Cove Marsh. These diversion ditches would discharge into East Foundry Cove and Foundry Brook, respectively. Such diversion would minimize inflow to East Foundry Cove Marsh and would, therefore, minimize resuspension of the highly contaminated sediments.

Long-term monitoring of the site would be performed in order to evaluate the performance of the no-action alternative. Monitoring would consist of annual inspection of the diversion ditches, as well as sampling and testing of East Foundry Cove Marsh sediments and water every three months during the first year and every six months thereafter for thirty years in order to detect sediment migration from the marsh.

Alternative CM-1

The no-action alternative for Constitution Marsh would address restriction of public access and long-term monitoring. Due to the relatively low concentrations of contaminants and existing difficult access, erection of a security fence is considered unnecessary. Only warning signs would be placed at prominent locations. Long-term monitoring of the site for thirty years would consist of sampling and testing of sediments and water in order to monitor contaminated sediment migration. Particular emphasis will be placed on monitoring the known cadmium hot spots to determine, if in fact, natural sedimentation and tidal flushing will reduce the cadmium availability. The sampling and testing would be done once every three months in the first year and every six months thereafter. In addition, bioassay/bioaccumalation studies would be performed periodically during the thirty year monitoring period.

Discusion

With respect to the no-action alternative, the results of the field investigation and the feasibility study indicate that there are significantly high levels of heavy metals contamination in the sediments of East Foundry Cove Marsh. These sediments are the source for elevated cadmium, nickel, and cobalt levels found in East Foundry Cove, West Foundry Cove, portions of the Hudson River, and Constitution Marsh biota. The sediment data specifically indicate:

- The existing concentrations of cadmium, nickel and cobalt measured in the sediments of East Foundry Cove Marsh show gross contamination.

- Although a notable decrease in contamination (four orders of magnitude) is observed with increasing distance from the East Foundry Cove Marsh outfall, most of the peripheral areas display elevated surficial contamination relative to the control site.

- The transport of contaminated sediments away from the outfall area follows patterns that are dictated by tidal and river flow hydrodynamics. Although not quantified, it is speculated that storm events may significantly influence dispersion of these sediments, especially in East Foundry Cove.

- Deposition of contaminated sediment is a function of tidal hydrodynamics (especially site-specific velocities), aquatic macrophyte densities, and river currents and conditions (Acres, 1985).

Key environmental and public health concerns include:

- Cadmium contamination in the biota is present in all trophic levels, with the benthic community containing the highest concentrations.

- Constitution Marsh, an Audubon Society-operated sanctuary is contaminated with cadmium.

- Fish-eating birds, waterfowl, and other terrestrial animals that feed in the site vicinity may be adversely affected due to bioaccumulation of cadmium in target organs. Little is know about the ability of animals to resist effects caused by cadmium uptake. Behavioral and reproductive disfunction are known to occur but are not well documented.

- The consumption of biota from fishing, hunting, and crabbing activities within Foundry Cove and Constitution Marsh exposes humans to cadmium contaminated foods. In addition, fish species migrate through the Foundry Cove on the way up the Hudson River to spawn (Acres, 1985).

The no-action alternatives focus on limited additional action to decrease the risks associated with the contaminated areas. These limited activities would fall into three main categories: increase public awareness; restrict access; and monitor conditions over time.

Increasing public awareness would be accomplished by holding public meetings and using the media to make people aware of the problem and to inform people of the risks associated with the heavy metal contamination.

Access to contaminated areas would be restricted to limit the direct contact of people with the contamination. These restrictions would take the form of fencing and putting additional limits on fishing and water sports.

Monitoring over time would identify any changes that occur due to movement or migration of contaminants resulting from natural proceses such as solubilization and erosion.

The no-action alternative calls for no remedial action to address the contaminated sediment of East Foundry Cove Marsh. As a result, cadmium, nickel, and cobalt concentrations would remain in the East Foundry Cove Marsh sediments in concentrations as high as 171,000, 156,000 and 6,700 mg/kg, respectively, in the outfall area.

In Constitution Marsh, the no-action alternative would leave existing contaminant levels unaltered. Two discrete locations of elevated concentrations of cadmium in sediments ranging from approximately 500 mg/kg to approximately 1,000 mg/kg, occur in the northern part of Constitution Marsh. The northern 40 ha of the marsh contain cadmium concentrations greater than 100 mg/kg. Cadmium is known to accumulate in some plant and animal species, and has achieved elevated concentrations in marsh wetland biota. These elevated concentrations may be sufficient to cause toxic effects, but available information is inconclusive. The marsh appears productive and shows no obvious symptoms of stress.

Under the no-action alternative, it is expected that species within East Foundry Cove Marsh will continue to bioaccumulate cadmium, community diversity will remain low for benthic organisms, cadmium levels in organisms will continue to be elevated, potentially increasing, and contaminated areas could redistribute and extend to a greater and larger area. Aquatic vegetation in the shallow areas of Foundry Cove, however, tends to act as a depository for contaminants from East Foundry Cove Marsh.

The major route of exposure for humans is through the ingestion of contaminated fish and shellfish. Under the no-action alternative, long-term health risks would remain since the critical exposure pathway of ingestion of contaminated fish and shellfish would not be eliminated or controlled. From a public health standpoint, exposure to cadmium is of special concern because:

- The 16-33 year half-life in the human body (WHO, 1972);
- Cadmium is stored in the soft tissues, mainly the kidney;
- Cadmium's resulting adverse health effects appear to be irreversible (USEPA, 1981); and
- EPA lists cadmium as a potential carcinogen (Sittig, 1981).

Foundry Cove is utilized by the people of Cold Spring for fishing and crabbing. The NYSDOH has issued a cadmium-related health advisory concerning the consumption of crabs from the Hudson River. NYSDEC recommends that no one should eat more than one meal of crabs from the Hudson River per week, that the crab's liver should not be eaten at all, and that women of child-bearing age and children under fifteen should never eat any Hudson River crabs.

Other possible socio-economic impacts which may result from the no-action alternative include depressed property values in the vicinity of the cove and reduced or no interest in development of areas around or overlooking the cove.

According to Ebasco's public health assessment, it has been concluded that less than 900 mg/kg cadmium in Foundry Cove and Constitution Marsh sediments poses no health-related concerns. Accordingly, because of the degree of contamination found in Constitution Marsh, there is only a minimal health concern because the lower concentrations of sediment contaminants have very small probabilities of exceeding acceptable human intake through the relevant exposure pathways.

Assuming that East Foundry Cove Marsh is remediated, in addition to the fact that significant levels of contamination will be removed from the source, natural processes may result in the deposition of clean sediment over the contaminated sediment in East Foundry Cove and in Constitution Marsh, as well. In general, substrate deposition in estuarine marshes keeps pace with the rise, which is approximately 3 millimeters per year (Renwier and Ashley, 1984). In time, therefore, the contaminated zone may be sandwiched between layers of low permeable material and become hydrologically isolated. Availability of this remaining cadmium to plant life and other biota should decrease with time as marsh sediments become covered with sediments.

In view of the extensive potentially detrimental effects resulting from dredging and removal of contaminated sediments from 40 ha of the Constitution Marsh, as well as the determination that cadmium levels up to 900 mg/kg pose no human health concern, the no-action alternative in Constitution Marsh becomes a viable alternative for consideration.

The cadmium in East Foundry Cove Marsh is highly available. As a result, no action in East Foundry Cove Marsh would allow a significant amount of cadmium contamination to remain, presenting a continuing threat to the environment and public health. Accordingly, no action is inappropriate for this sub-site, and has been deleted from further consideration. In Constitution Marsh, the cadmium is less available than in East Foundry Cove Marsh. Because of the potentially significant disruption of a sensitive ecosystem by implementing a remedial alternative in Constitution Marsh, no action would be the least damaging remedial alternative in terms of environmental impacts.

II. HYDRAULIC DREDGING/THICKENING/FIXATION/OFF-SITE DISPOSAL:

Alternative ECM-2

The major features of this alternative include hydraulic dredging of East Foundry Cove Marsh, sediment chemical fixation and off-site disposal, dredging water treatment and disposal, restoration of the marsh, and long-term monitoring.

Hydraulic dredging over an area of approximately 5 ha in East Foundry Cove Marsh would be performed to remove contaminated sediment to a depth of approximately 0.6 m from the marsh, outfall area, and channels, as well as the area in East Foundry Cove in the vicinity of the channel outlet encompassed by the 1000 mg/kg isopleths of surficial cadmium (See Figure 9.) Hydraulic dredges, able to remove and transport sediment in liquid slurry form containing approximately 10-20% solids, require that a 2 m water depth be maintained for mobility. In order to maintain the required water depth, a containment dike approximately 1000 m long and 2.5 m high, with 3:1 side slopes would be constructed to surround East Foundry Cove Marsh. This earth containment dike would also contain sediments generated during dredging, and provide truck access around the site. In addition, a silt curtain would be constructed around the dredging site to contain suspended sediments during dike construction.

Following flooding, the marsh vegetation would be harvested in order to reduce the vegetation in the dredge area. The harvested vegetation would be dumped onto a conveyor that would load it directly to trucks for transport to an appropriate disposal facility. Whether this facility is a sanitary landfill or a hazardous waste disposal facility will be determined after an analysis of the vegetation to determine whether or not it can be considered hazardous.

Finally, the root mat and sediments would be removed. Approximately 23,000 m^3 of sediments would be removed from East Foundry Cove Marsh over a period of about four to five months. The pumping rate of the water-sediment dredge slurry with approximately 20% solids would be approximately 63 liters per second.

The dredged slurry would be pumped through a floating piping system to a treatment system located on the former battery facility property. After thickening, the sediment would be chemically fixated.

Based upon the bench scale tests performed by two companies on the contaminated sediments, two possible fixation process scenarios were considered.

The "CHEMFIX" process, developed and patented by Chemfix Technologies, Incorporated, is based upon a chemical treatment utilizing thickened/dewatered sediments, dry reagent, and liquid reagent. The dry reagent is made from clay and limestone and is similar to portland cement. The liquid reagent is made from high purity beach sand and soda ash which has been pulverized, calcinated and dissolved in water.

In this process scenario, the sediment and dry reagent would be throughly blended in a high powered mill. After completion of the blending, the liquid reagent would be injected into the mass, followed by further blending. At this point, a rapid chemical reaction would occur, transforming the product into a gel that binds the metals within its matrix. The gel has a friable, clay-like appearance.

The second of bench scale tests was performed by Associated Chemical and Environmental Services. In this process, measured quantities of waste contaminated sediment and fly ash would be introduced into a mixing unit. A rotating mixing blade would be introduced into the mixer for a brief period, then removed. A specified amount of lime would be added, followed by a second slightly longer mixing period. A material of damp soil consistency would be produced which would bind the metals within its matrix.

For both processes, EP toxicity tests were performed on the product, indicating that the product was not hazardous.

After fixation, 47,000 m^3 of the processed sediments would be loaded onto trucks for transport to a local sanitary landfill as either a daily cover or as a waste.

The supernatant from the thickeners would be pumped into clarifier tanks where alum and polymer would be added and mixed in order to precipitate the suspended solids. The clarified supernatant would then be decanted, tested, and returned to the dredging cell via a pumping system. The settled solids from the clarifiers would be pumped back to the thickener tanks and be treated in the same manner as the contaminated sediments.

After completion of the hydraulic dredging operation, the marsh would be restored by replacement of sediment and replanting of vegetation.

Replacement of the sediments would be accomplished by backfilling of the marsh with approximately 0.3 m of clay having a high affinity for cadmium and 0.3 m of topsoil. This process would require approximately 14,000 m^3 of clay and approximately 14,000 m^3 of topsoil to replace the marsh to approximately its original elevation. The containment dike would be used as a portion of the backfill material. Revegetation of the marsh would follow.

To minimize the disturbance of the replaced sediments in East Foundry Cove Marsh, the storm sewers would be diverted in the same manner as described in Alternative ECM-1.

In order to evaluate the performance of this remedial action, a long-term monitoring program would be implemented. It would consist of annual site inspection, as well as sampling and testing of sediments and water. Sampling/testing would be performed every three months during the first postconstruction year and every six months thereafter for a period of thirty years.

Alternative CM-2:

The major features of this alternative are hydraulic dredging of the marsh, sediment chemical fixation and disposal off-site, dredging water treatment and disposal, marsh restoration, and long-term monitoring.

Hydraulic dredging would be performed to remove contaminated sediments to a depth of approximately 0.3 m. Most of the features associated with dredging in Constitution Marsh are essentially the same as discussed previously.

The total area of the Consitution Marsh is approximately 117 ha. The area to be dredged to clean up the sediments with cadmium concentrations above 100 mg/kg is approximately 40 ha in the northern portion of the marsh.

In this operation, the dredge area would be divided into two cells in order to maintain tidal flow between Constitution Marsh and Foundry Cove. Each cell would be approximately 20 ha, and dredging would be performed in one cell at a time. The cell would be enclosed by an 2.4 m earthen dike 4 m wide at the top with 3:1 slopes in order to maintain a level of 1 m of water in the cell. Outside the dike, a silt curtain would be erected to contain the transport of sediments outside the cell during dike construction and dredging.

As the sediment is dredged, the slurry would be pumped through a floating piping system to an on-site treatment facility. It is anticipated that approximately 120,000 m^3 of sediments would be dredged from the marsh. Considering the 10-20% solids content of the dredged slurry, it is estimated that approximately 600,000 m^3 of slurry would be generated. The treatment for the sediment and the dredging water would be the same as indicated previously.

The fixated sediments, which would amount to approximately 250,000 m^3, would be disposed of off-site in a local landfill as described previously.

After completion of the dredging in the cell, clean fill would be deposited to attain predredging contours to the maximum extent possible. As much of the dredged area would be replanted with cattail-arrow arum as is practical.

The aqueous treatment system for supernatant from the thickeners would be the same as described previously.

The marsh restoration procedures and long-term site monitoring would be the same as described previously.

Discussion

The removal of the bulk of the cadmium source from East Foundry Cove Marsh would eliminate a significant source of contaminated sediment being transported to Foundry Cove and Constitution Marsh. The mean concentration of cadmium in East Foundry Cove Marsh sediment is about 28,000 mg/kg, compared to about 1100 and 180 mg/kg in sediments of Foundry Cove and Constitution Marsh, respectively.

Dredging in East Foundry Cove Marsh would achieve sediment cadmium concentrations of 100 mg/kg or less. Since most of the dredged area would be recontoured with clay and clean fill, the residual cadmium should be isolated from hydrologic and biologic processes. Dredging of contaminated sediments, therefore, would remove what is believed to be the primary source of cadmium which is currently exposing the larger Constitution Marsh complex to potential toxic effects. It would also minimize possible direct contact of fish and wildlife with highly contaminated sediments.

Removal of the East Foundry Cove Marsh, however, would destroy approximately 5 ha of cattail-arrow arum habitat. This area, however, is considered small relative to the 117 ha similar habitat in Constitution Marsh. Effects from the lost marsh will be largely temporary, as a cattail-arrow arum marsh would be reconstructed on the same location after recontouring with clean fill. The re-established marsh would support lower densities of plants and would contain less underlying organic muck. It would be less productive and less effective as a sediment trap, but both these functions would, with time, tend to approach pre-cleanup levels.

One of the primary concerns associated with revegating the marsh is the potential that the revegetation will not be successful. Arrow arum is currently the dominant species in the marsh. A modification in the ecological nature of the marsh may occur, however, since cattails tend to spread faster than arum. In addition, unless the organic content of the replacement soils is similar to the excavated sediments, it is possible that the ability for the cattails and arrow arum to spread may be impeded. It is believed that maintenance and handcutting for one to two years, however, will prevent undesirable plant species from establishing themselves (ERT, 1986), improving the likelihood that arrow acum will reestablish itself. Despite the concerns, it is believed that the risk of failure to revegatate the marsh is small.

Since the existing sediment contours would be replaced, remediating East Foundry Cove Marsh would not appreciably impact the exchange of tidal waters between Foundry Cove and Constitution Marsh. In addition, no long-term major impacts on wetland communities are anticipated as a result of interfering with the East Foundry Cove Marsh.

Impacts associated with removal of 40 ha of mostly cattail vegetation in Constitution Marsh may be extensive. Almost half of the nesting area available for least bittern, a New York State species of "special concern," could be temporarily eliminated. The quality of undredged portions of the cattail marsh as nesting habitat would likely be reduced due to increased human activities occurring over at least a two year period. Waterfowl use of the site as a resting area during spring and fall migration could be similarly affected. A small portion of the dredged area includes floating mats of cattail, which are an unusual feature found in tidal marshes. Restoration of such floating mats is probably not possible. Dike construction may resuspend contaminated particulates, increasing exposure to aquatic and wetland biota (Ebasco FS, 1986).

Removal of the extremely high levels of contaminated sediments from East Foundry Cove Marsh as called for in Alternative ECM-2 would eliminate further transport of highly contaminated sediments to East Foundry Cove and Constitution Marsh, significantly reducing the cadmium availability to the biota.

It is believed that implementation of Alternative CM-2 would cause extensive environmental degradation in Constitution Marsh far outweighing the benefits that would be realized by dredging and removal of the contaminated sediments. The dredging and removal options require diversion of tidal waters around the work areas, affecting tidal flow patterns. If restoration does not achieve pre-cleanup conditions and contours, the existing tidal flow patterns may not return. This would adversely affect the entire Constitution Marsh. Even though revegetation of the 40 ha marsh would be attempted, it may prove extremely difficult by virtue of the extensive area involved. Because of the need to install access roads, even the removal of the hot spot areas in Constitution Marsh may result in significant environmental impacts. Constitution Marsh is an important resource, and any potential loss of all or a part of it would be very difficult to justify. For the forgoing reasons, Alternative CM-2 was deleted from further consideration.

III. HYDRAULIC DREDGING/THICKENING/FIXATION/ON-SITE DISPOSAL:

Alternative ECM-3

The major features of this alternative include hydraulic dredging of East Foundry Cove Marsh, sediment chemical fixation and on-site disposal, dredging water treatment and disposal, restoration of the marsh, and long-term monitoring.

This source control alternative is exactly the same as Alternative ECM-2 except that the fixated sediments will be disposed of on-site.

Under this alternative, rather than off-site disposal, the fixated sediment would be transported from the curing area to a 2.7 ha landfill constructed on-site, for disposal. While an on-site, non-RCRA disposal facility would be viable, as an added measure of protection to public health and the environment, the landfill would be constructed in accordance with RCRA

requirements for hazardous waste landfills. It would contain a double liner, including leachate collection and leak detection systems, and a RCRA cap would be placed over the landfill following completion of disposal operations. The total fixated volume to be disposed of from East Foundry Cove Marsh would be approximately 47,000 m^3.

Under this alternative, the storm sewers would be diverted in the same manner as described in Alternative ECM-1.

Long-term monitoring of the site and the RCRA landfill would follow completion of the restoration of the site.

Discussion

Because of the sensitive wetland and historic areas, the only site available with adequate size for on-site disposal would be the former battery plant grounds.

The landfill design consists of a clay liner, synthetic liners, capping with runoff collection and drainage to East Foundry Cove. This design is intended to assure virtually no leachate generation. Lost recharge to the aquifer, because of the capping and drainage design, is estimated to be equivalent to less than 0.6 liters per sec.

The fixated sediments derived from East Foundry Cove Marsh meet the RCRA EP Toxicity Test and would be "non-hazardous." Cadmium concentrations in test leachate were less than 1 mg/kg. Even if such materials were disposed of in unlined and uncapped landfill, the threat of groundwater contamination would be considered relatively low.

Because of the very low solubility and mobility of fixated sediments and high reliability of RCRA-designed landfills, the potential of ground-water contamination is considered very small.

This proposed on-site landfill is estimated to be adequate for the fixated sediments from East Foundry Cove Marsh, but would not, however, be able to accommodate the fixated sediments from Constitution Marsh, or East Foundry Cove, West Foundry Cove, and the Cold Spring pier area if removal and fixation of sediments from these areas is required.

Because the landfill would be constructed in a residential area, and because the available area is not sufficient to accommodate any dredged sediments from the remaining portions of the site, on-site disposal for East Foundry Cove Marsh may not be consistent with other actions eventually selected for other portions of this site. Therefore, this alternative was deleted from further consideration.

IV. HYDRAULIC DREDGING/SEDIMENT THICKENING AND DEWATERING/ OFF-SITE DISPOSAL

Alternative ECM-4:

The major features of this alternative include hydraulic dredging of East Foundry Cove Marsh, sediment thickening, dewatering and off-site disposal, dredging water treatment, restoration of the marsh, and long-term monitoring.

This alternative is the same as Alternative ECM-2 except that the sediment would be thickened and dewatered, but not fixated. The dewatered sediments would, therefore, remain as hazardous waste and would be disposed of off-site in a permitted hazardous waste facility. The dewatered sediment would be transported to the Model City, New York hazardous waste landfill, approximately 640 km from the site. It is estimated that 23,000 m^3 of dewatered sediments would be generated over four months. Discussions with the Model City facility indicated that adequate capacity is available and no problem is anticipated in handling cadmium/nickel/cobalt-contaminated sediments.

The aqueous treatment system for effluent from the thickeners would be the same as ECM-2. The filtrate from the dewatering vacuum filters would be pumped back to the thickeners.

Under this alternative, the storm sewers would be diverted as described in Alternative ECM-1.

Long-term monitoring would follow completion of the restoration of the site.

Alternative CM-3:

The major features of this alternative include hydraulic dredging of Constitution Marsh, sediment thickening, dewatering, and off-site disposal, dredging water treatment, marsh restoration, and long-term monitoring.

Hydraulic dredging of Constitution Marsh would be the same as in Alternative CM-2.

The sediment treatment would be the same as in Alternative CM-2 except that dewatering would be perfomred instead of fixation. The approximately 120,000 m^3 of dewatered sediments, which would remain as a hazardous waste, would be loaded onto trucks as described in Alternative ECM-2. It would then be transported to the RCRA landfill at Model City, New York for disposal. Model City landfill authorities have indicated that adequate capacity is available and that the dewatered sediments contaminated with heavy metals do not pose any problems.

The aqueous treatment system for effluent from the thickeners would be the same as in Alternative ECM-2. The filtrate from the dewatering vacuum filters would be pumped back to the thickeners. Marsh restoration and long-term monitoring would be included.

Discussion

According to regulations promulgated pursuant to the 1984 RCRA amendments, prior to disposal, the liquid content of the dewatered sediments must be determined. Since long-distance transport of these sediments to the disposal facility might cause separation of "free liquids" from the sediments, it is possible that the sediments might not be acceptable for disposal at the facility when they arrive (ERT, 1986).

While the costs associated with off-site disposal of the cadmium-contaminated sediments are not significantly greater than fixation and sanitary landfill disposal, the possibility of hauling losses of hazardous wastes and the consumption of limited off-site hazardous waste landfill capacity, and the possibility that the sediments may not be acceptable for disposal, warrant the elimination of these alternatives from further consideration.

V. CONTAINMENT

Alternative ECM-5:

The major features of this alternative include containment of the undisturbed sediments in-situ, construction of a new marsh adjacent to the containment area, and long-term monitoring of the site.

Containment of the contaminated sediments in East Foundry Cove Marsh would be accomplished by construction of a 610 m long, 2.5 m high containment dike along the southern edge of the marsh and a multi-layer cap consisting of:

- Geotextile layer (bottom)
- 0.3 m gravel layer
- 15 cm Armorform layer
- 0.3 m topsoil layer
- Hydro-turf layer and grass (top)

An open field habitat would be established on the surface of the containment area. A new marsh of equal area, approximately 5 ha, would be constructed in East Foundry Cove adjacent to the containment area. The new marsh would be developed in generally the same way as presented in Alternative ECM-2.

Long-term monitoring would consist of annual inspection of the cap and restored marsh as well as sampling and testing of sediments and water in East Foundry Cove. Sampling and testing to monitor sediment releases from the containment area and to evaluate cap performance would be performed every three months for the first year following construction. It would then be performed every six months for a period of thirty years.

Discussion:

Containment of the contaminated sediments underlying East Foundry Cove Marsh would immobilize the cadmium which is the source of cadmium currently being transported into East Foundry Cove and Constitution Marsh. Containment would also prevent direct exposure of aquatic and wetland biota to highly contaminated sediments. Containment, however, is not considered as reliable as removal, and extensive monitoring of the containment structure would be required.

Approximately 5 ha of the East Foundry Cove Marsh cattail-arrow arum would be replaced by the open field habitat established on the surface of the containment area. The effects associated with loss of marsh habitat would be minimized by construction of an additional cattail-arrow arum marsh of comparable area in the south side of East Foundry Cove or west of the railroad embankment immediately north of Constitution Island. This new marsh, however, may influence the tidal flow patterns within East Foundry Cove, possibly eliminating flow to some areas and increasing flow velocity in other areas. This could influence the volume of Hudson River water exchanged with the northern part of Constitution Marsh. There is some evidence that marsh productivity correlates with tidal flushing, and therefore, such interference could negatively impact Constitution Marsh.

From the environmental viewpoint, the containment alternatives for East Foundry Cove Marsh and for East Foundry Cove (should this alternative be selected in the subsequent ROD) are not compatible with each other. If both areas are covered with armormat, because of the impact on tidal flow to Constitution Marsh, the environment may be affected to such an extent that severe adverse environmental impacts may result.

Because of the potentially significant environmental impacts associated with the containment alternative, Alternative ECM-5 has been deleted from further consideration.

It has been suggested that partial removal options which would include limited dredging within East Foundry Cove Marsh, so as to reduce the potential impact on the existing vegetation while removing the highly contaminated sediments from the outfall and existing flow channels, be considered. While this operation would probably provide the maximum cadmium removal per cubic meter of dredged sediment while minimizing the short-term adverse effects of a dredging operation in the entire East Foundry Cove Marsh area, it would allow areas in East Foundry Cove Marsh with contaminant levels in the tens of thousands to remain. In addition, in the early 1970s, approximately 3,500 m^3 of cadmium-contaminated sediments with concentrations greater than 900 mg/kg were removed from the outfall area, channels, and a portion of East Foundry Cove. Since it is believed that the battery facility did not discharge appreciable quantities of cadmium contamination to Foundry Cove after the dredging operation, and since it is apparent that this dredging operation was unsuccessful in alleviating the contamination problem, not only would the threat to the environment and public health remain by limited dredging, but the undredged contamined sediment would probably migrate and deposit in the channel areas, necessitating further dredging.

Table 14 summarizes the results of the alternative evaluation process, and Table 15 summarizes the annual operation and maintenance the costs associated with the remedial alternatives.

Community Relations

Throughout the remedial investigation/feasibility study process, all data and information were made available to the public via a public repository.

A public meeting was held in the Municipal Building on September 26, 1985 to discuss the results of the Acres RI/FS.

After publicly releasing the draft supplemental RI/FS on August 15, 1986, a public meeting was held on August 26, 1986. The public meeting, announced by a press release and direct mailing, indicated that the meeting was to be held in the Municipal Building and that the public comment period would end on September 15, 1986. Attached is a list of attendees. In response to a request by the PRPs for an extension of the public comment period, the comment period expiration date was extended to September 23, 1986.

A responsiveness summary is attached. This document summarizes the comments on the supplemental remedial investigation/ feasibility study report, includes meeting notification documents, and summarizes the public meeting comments and responses to those comments (see Attachment 1).

Consistency With Other Environmental Laws

The recommended remedial alternative complies with all substantial requirements of the Resource Conservation and Recovery Act, the Clean Water Act, and the Clean Air Act.

In addition, appropriate actions either have already been taken or will be taken to ensure that the recommended remedial alternative complies with the requirements of the following environmental statutes and executive orders:

- Endangered Species Act - Two federally listed endangered species (i.e., the bald eagle and the shortnose sturgeon) are known to be transient inhabitants in the vicinity of the Marathon Battery Company site. In order to ensure that these species are not adversely impacted by the recommended remedial alternative, informal consultation pursuant to Section 7 of the Endangered Species Act will be initiated as soon as possible. Based on the results of the informal consultation, formal consultation and the development of appropriate mitigation measures will be developed, if necessary, during the remedial design of the project.

- National Historic Preservation Act - There are several properties in the vicinity of the Marathon Battery Company site that are listed on the National Register of Historic Places. In addition, there is a high probability that the area surrounding the site contains significant prehistoric resources. In order to properly assess the impact of the project on significant cultural resources, a cultural resources site recognition survey will be performed during remedial design. If significant cultural resources will be impacted by the project, appropriate mitigation measures will be developed and implemented prior to initiation of construction.

- Coastal Zone Management Act - The Marathon Battery Company site is located within the coastal zone as designated in the New York State Coastal Zone Management Plan. Accordingly, a determination of the project's consistency with this Plan will be obtained from the New York Department of State prior to the initiation of the construction phase of the project.

- Executive Order 11990 (Wetlands Protection) - The recommended remedial alternative includes the dredging of several hectares of wetlands. A detailed wetlands restoration plan will be developed during remedial design and implemented during construction to mitigate this adverse impact.

- Executive Order 11988 (Floodplain Management) - The Marathon Battery Company site lies within the 100 year floodplain as designated by the Federal Emergency Management Agency. The recommended remedial action requires the unavoidable encroachment on the floodplain, however, the project will not result in long-term adverse impacts on the floodplain or flooding levels.

Based on the above, and the actions taken during the preparation of the RI/FS for this project, EPA has determined that the review of this project is functionally equivalent with the requirements of the National Environmental Policy Act.

Recommended Alternative

According to 40 CFR Part 300.68(i), the appropriate extent of a remedy will be based upon the selection of a cost-effective remedial alternative which effectively mitigates and minimizes damage to and provides adequate protection of public health, welfare, and the environment. Eight alternatives, including two no-action alternatives, were evaluated. Based upon the above analysis of these alternatives, Alternative ECM-2, hydraulic dredging, sediment thickening, fixation, and off-site disposal is recommended as the most cost-effective remedial measure for East Foundry Cove Marsh. Alternative CM-1, no action, is recommended for Constitution Marsh.

While the bench scale treatability testing of fixation processes indicate that the heavy metals in question can be tied up in the matrix created by this process, during the design phase, pilot-scale studies will be performed to quantify better the effectiveness and production rates of a largescale treatment operation.

Because of the unique educational and scientific opportunities presented by remediating the East Foundry Cove Marsh portion of the site, it is recommended that an interpretation center be established at the site so that interested members of the public and the scientific community can visit the site during and after site revegetation.

Operation and Maintenance

Maintenance and hand-cutting will be required for at least one to two years to prevent the invasion and/or establishment of undesirable plant species. Besides continued monitoring for thirty years, there are no other long-term operation and maintenance requirements associated with these alternatives since the source will be removed.

Schedule

Activity	Date
- Final Record of Decision	September 30, 1986
- Amend Memorandum of Understanding (MOU) for Design	October 31, 1986
- Start Design	November 30, 1986
- Complete Design	August 31, 1987
- Amend MOU for Construction	September 30, 1987
- Solicit Construction Proposals	October 31, 1987
- Award Contract for Construction	January 1, 1988
- Start Construction	March 31, 1988
- Complete Construction	March 31, 1991

Future Actions

Upon completion of the Supplemental RI/FS for West Foundry Cove, the Hudson River in the vicinity of the Cold Spring pier, and the former battery manufacturing facility portion of the site, and bioassay work in East Foundry Cove, a ROD will be prepared to recommend a remedial solution for this portion of the site.

To better characterize the link between the levels of cadmium contamination in East Foundry Cove sediments and bioaccumulation in aquatic fauna, bioassay work will be performed in East Foundry Cove.

Because the battery plant discharged for number of years into the Hudson River via the outfall at the Cold Spring pier, only a limited sampling program was conducted in this area. It was believed, at that time, that since the river at this point flows at a significant velocity, little or no heavy metal contamination would be detected in this area. Sediment contaminant levels ranging from less than one to 2200 mg/kg were detected, however, since there is no clear definition of the extent of the contamination in this area, additional sampling in the Hudson River will be performed.

In West Foundry Cove a similar situation exists with the available information being too restrictive to enable the costing and ranking of alternatives. Cores need to be taken farther out into the Hudson River and farther to the south closer to Constitution Island.

Additional sampling is also necessary in the former battery facility and the surrounding grounds.

The bioassay investigation and the FS planned for the West Foundry Cove, Hudson River in the vicinity of the Cold Spring pier, and the former battery facility portion of the site is scheduled for completion in April 1987. Since dredging, sediment thickening, fixation, and sanitary landfill disposal of the cadmium-contaminated sediments is a possible remedial alternative for this portion of the site, coordination of remedial design and remedial implementation activities should be phased in such a way to ensure cost-effective managment of consultant/contractor resources, equipment, and schedules.

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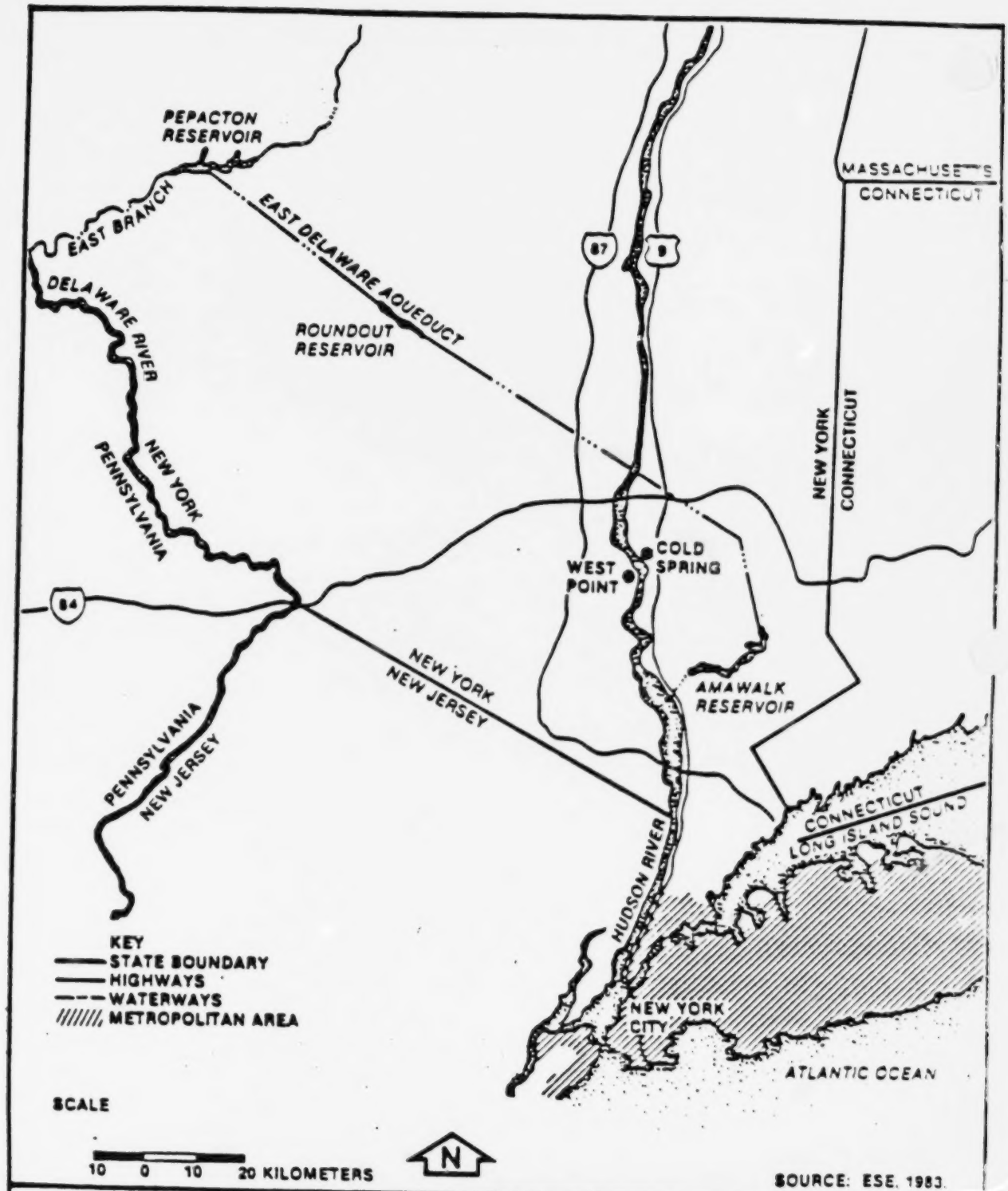
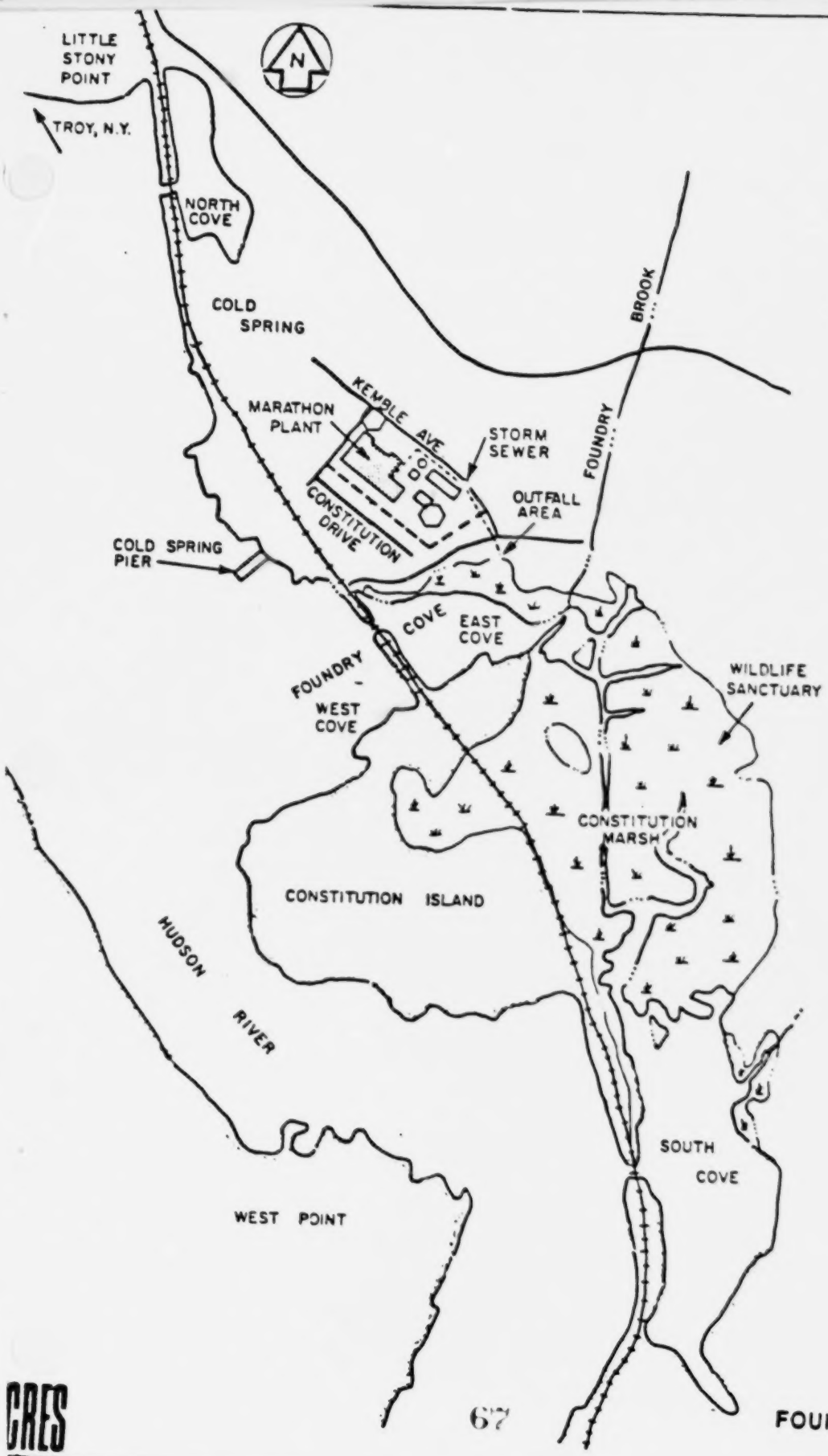
Figures and Tables



SITE LOCATION MAP OF COLD SPRING

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

Figure 1



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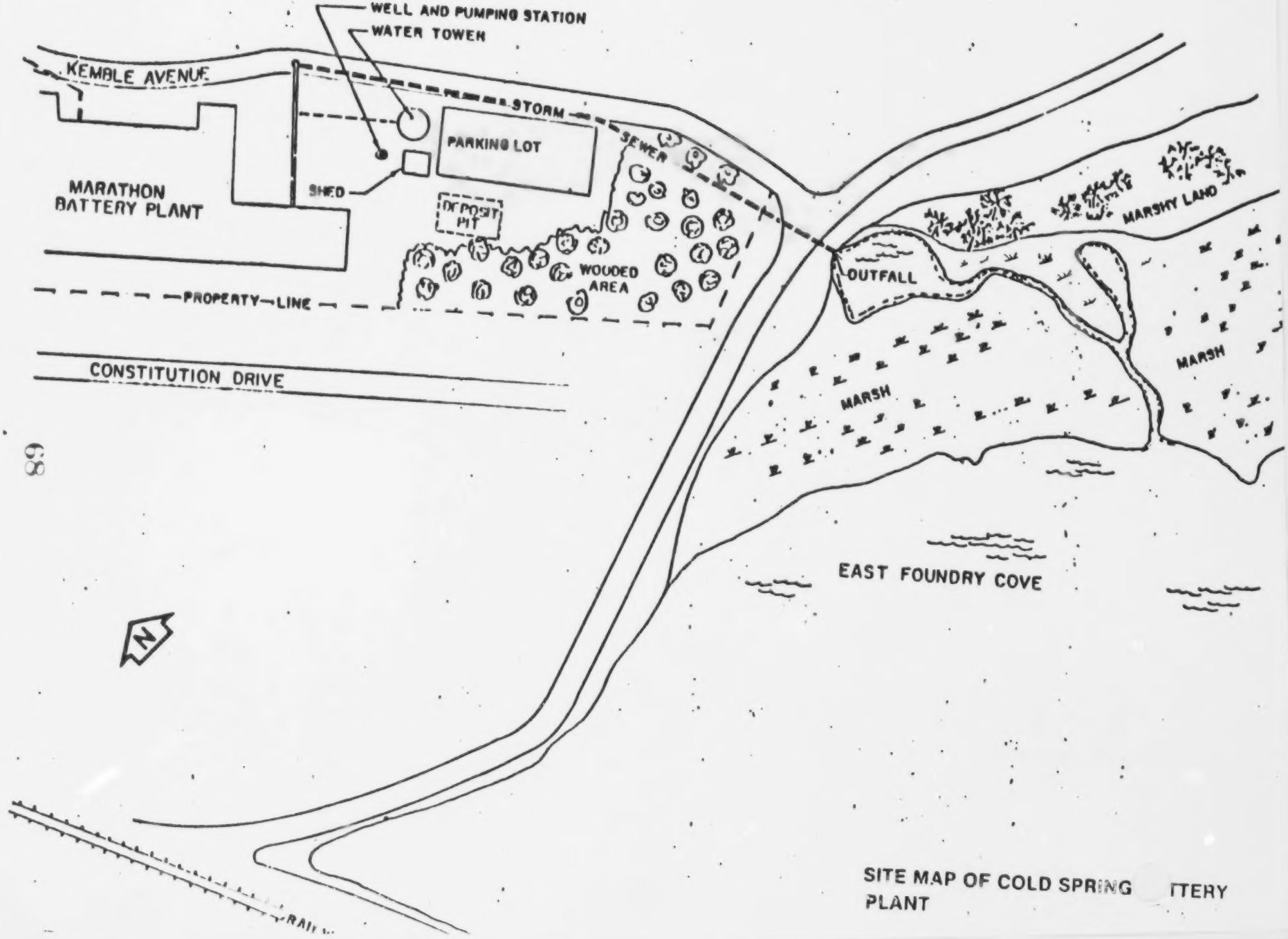
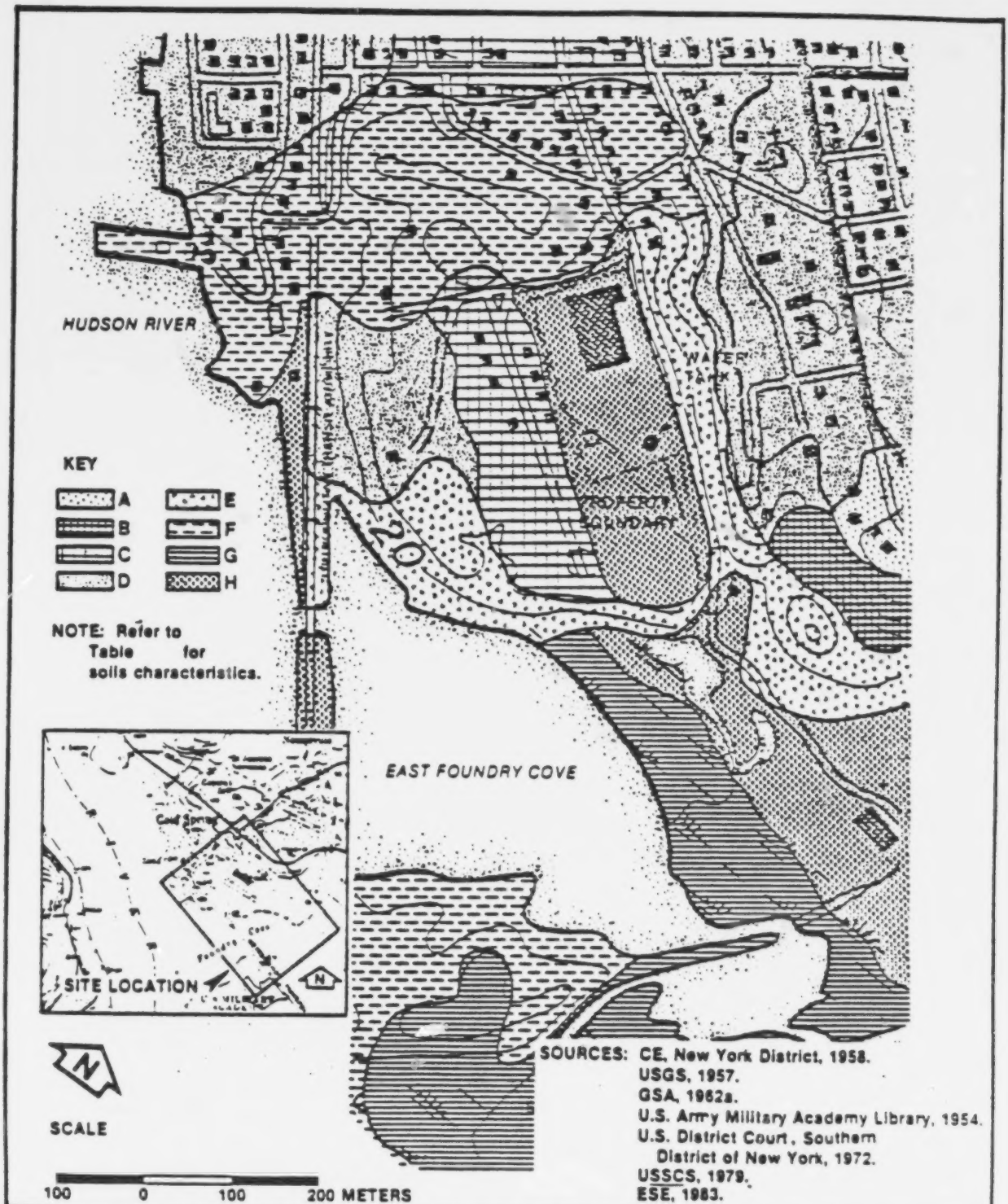
FOUNDRY COVE AND VICINITY

Figure 2



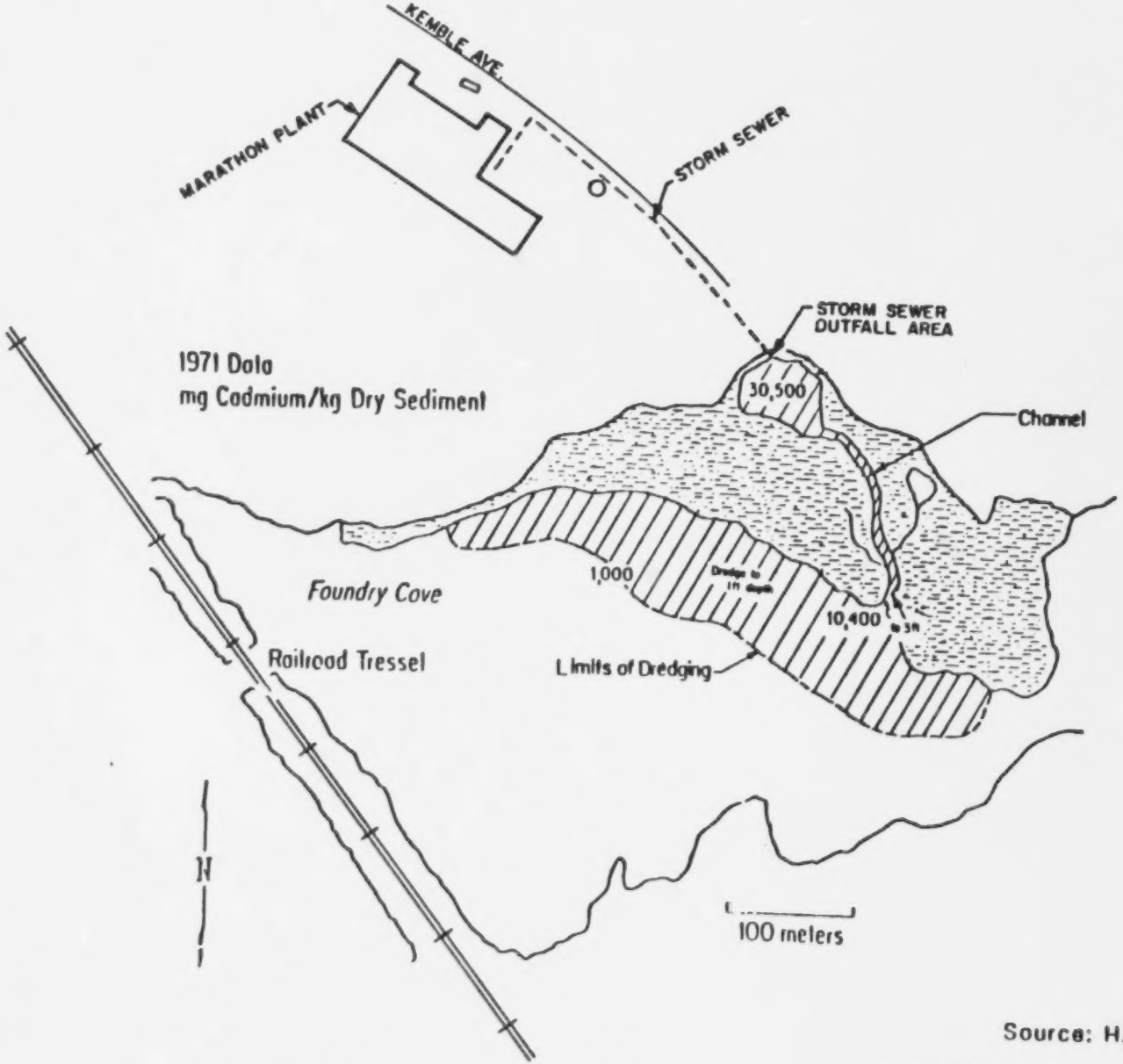
SITE MAP OF COLD SPRING ITTERY
PLANT



SOILS MAP OF THE COLD SPRING BATTERY PLANT AND SURROUNDING AREA

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

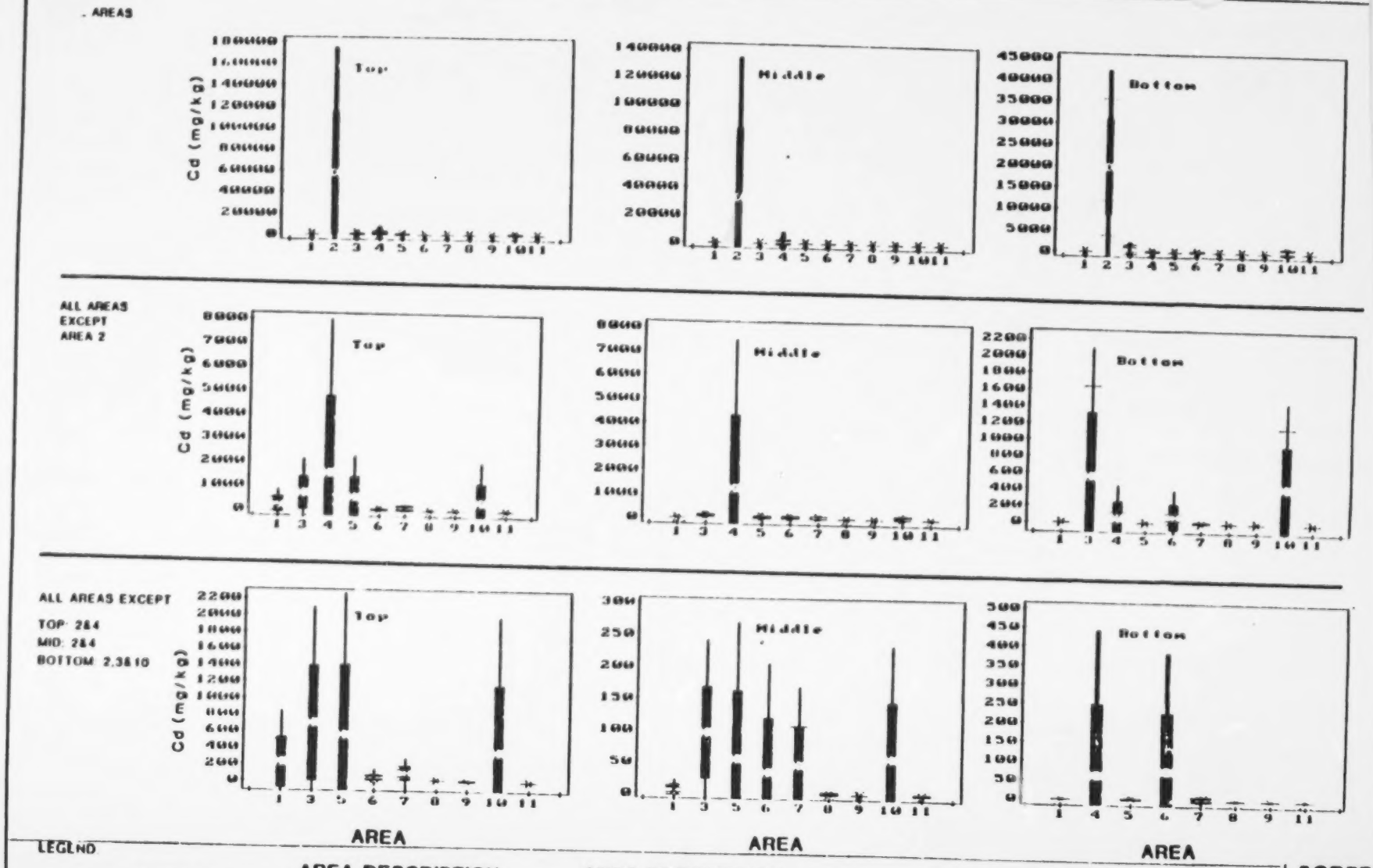
Figure 4



Source: HAZEN, 1981

Areas dredged in 1973 subsequent to 1972 dredging of discharge and channel areas

Figure 5



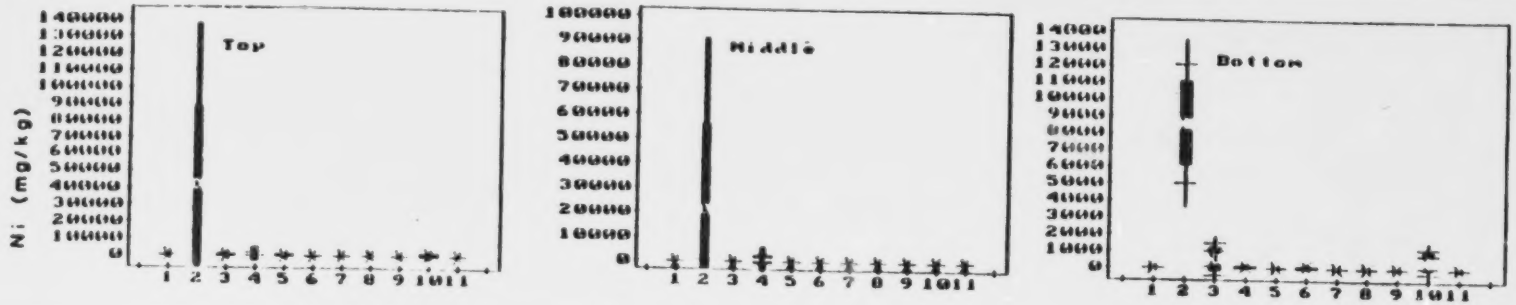
ACRES

CADMIUM CONCENTRATIONS IN SEDIMENTS

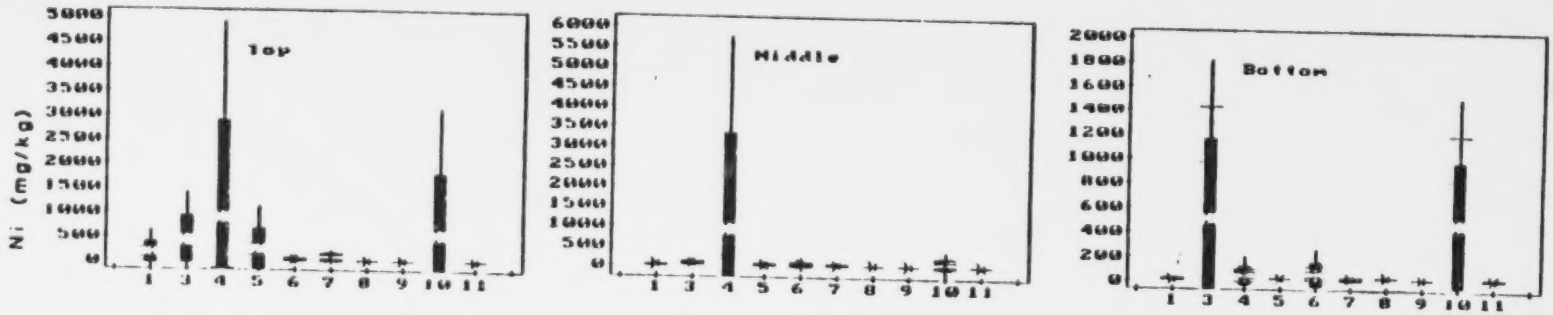
MARATHON BATTERY SITE

Figure 6

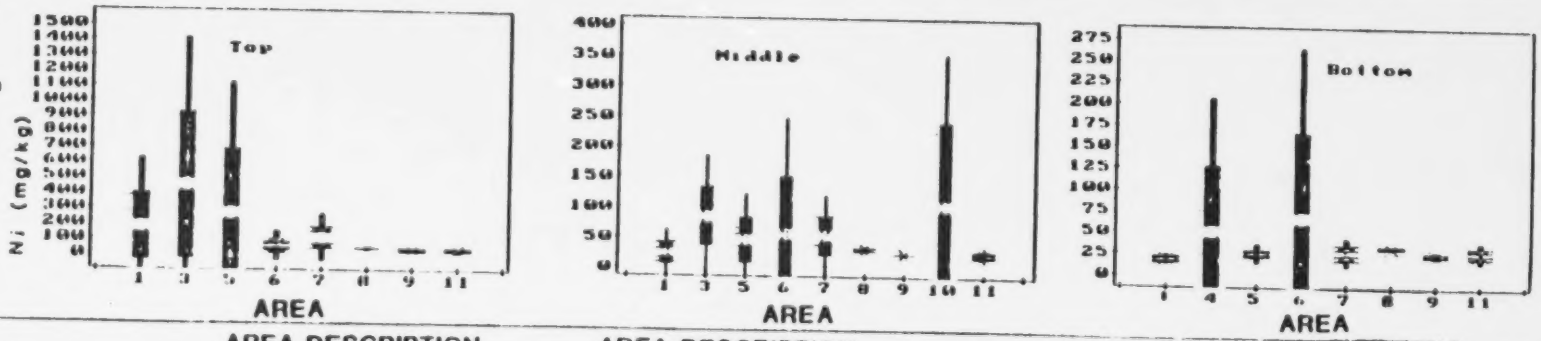
ALL AREAS



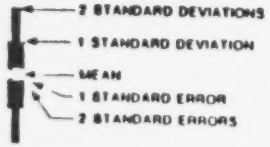
ALL AREAS EXCEPT AREA 2



ALL AREAS EXCEPT
TOP: 2, 4, & 10
MID 2 & 4
BOTTOM: 2, 3, & 10



LEGEND



AREA DESCRIPTION

1- CONSTITUTION MARSH
2- EAST COVE HOT SPOT
3- EAST COVE MARSH
4- EAST COVE
5- EAST COVE SUPPLEMENTAL
6- WEST COVE

AREA DESCRIPTION

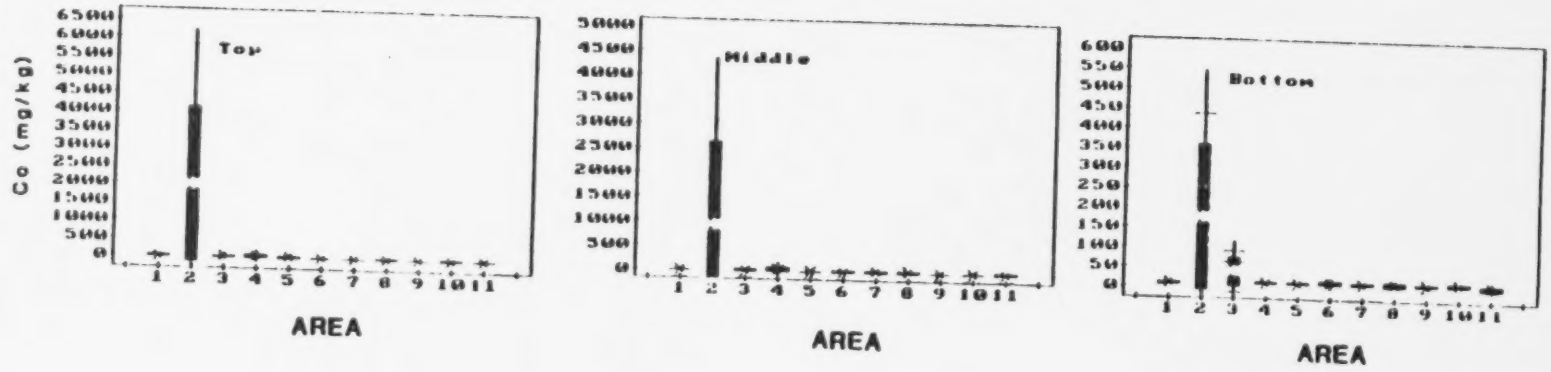
7- WEST COVE SUPPLEMENTAL
8- NORTH COVE
9- SOUTH COVE
10- PIER SITE
11- TIVOLI BAY

ACRES

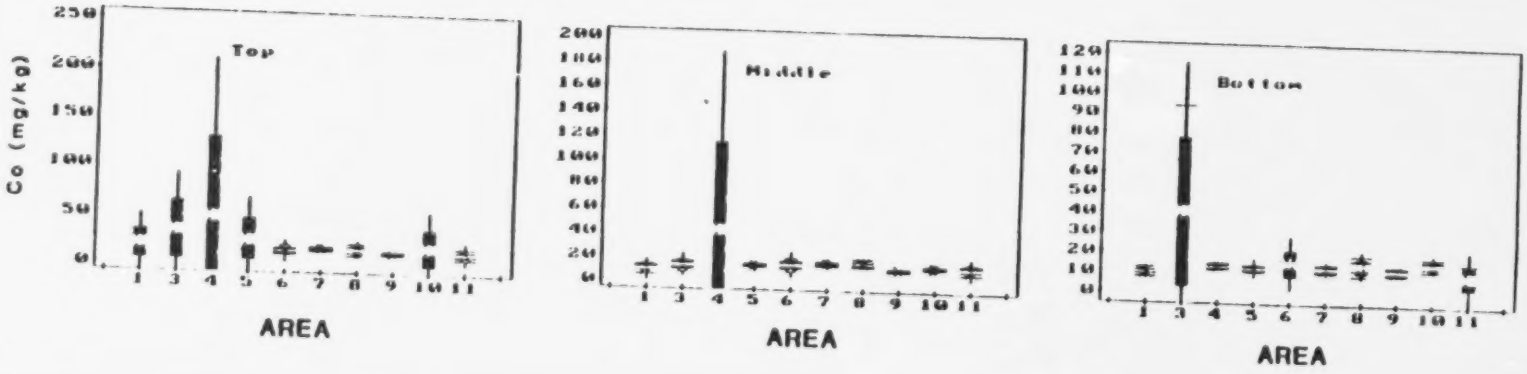
NICKEL CONCENTRATIONS IN SEDIMENTS

MARATHON BATTERY SITE Figure 7

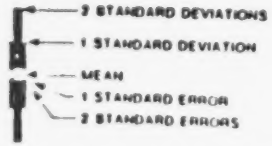
ALL AREAS



ALL AREAS EXCEPT AREA 2



LEGEND



AREA DESCRIPTION

1- CONSTITUTION MARSH
2- EAST COVE HOT SPOT
3- EAST COVE MARSH
4- EAST COVE
5- EAST COVE SUPPLEMENTAL
6- WEST COVE

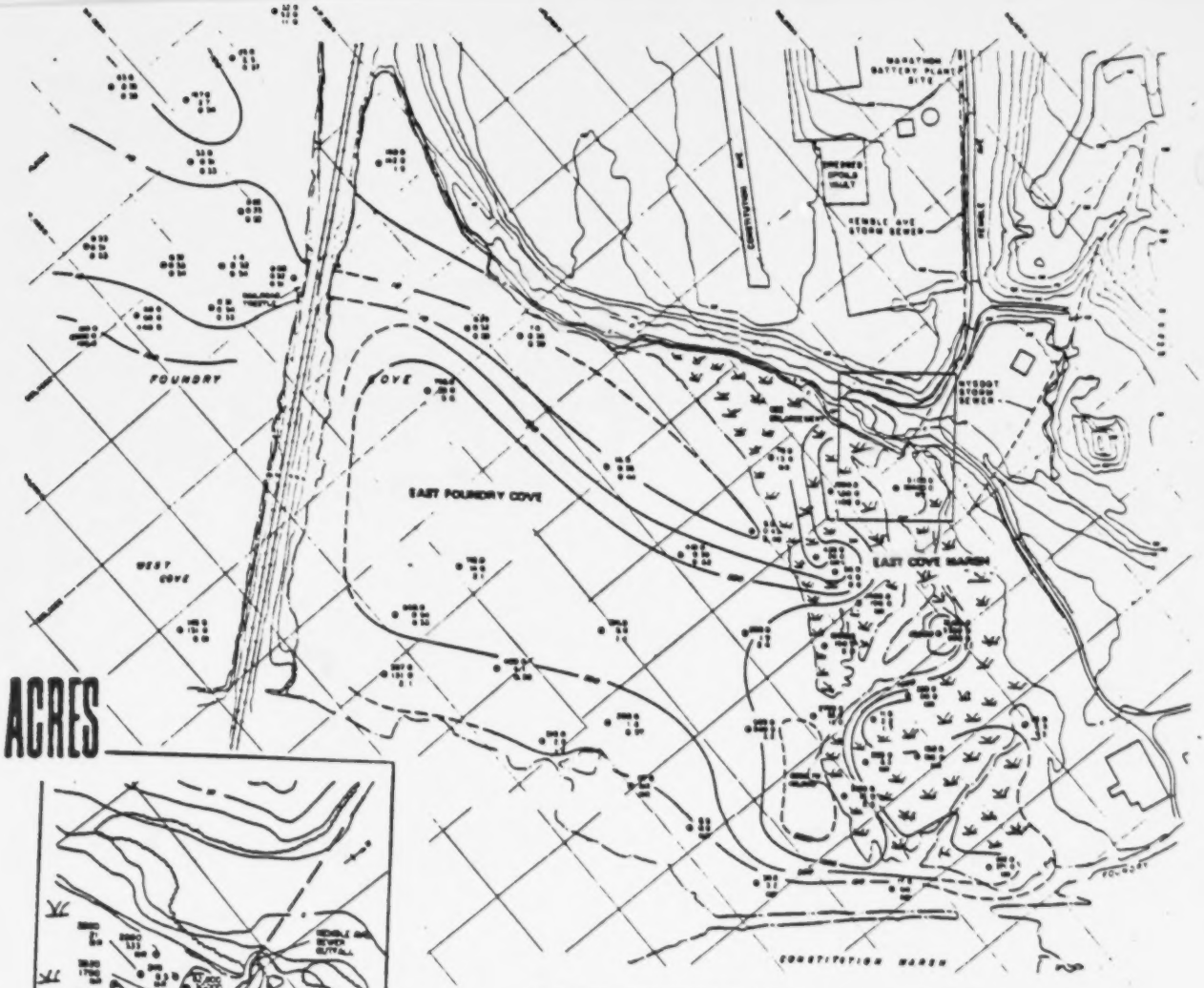
AREA DESCRIPTION

7- WEST COVE SUPPLEMENTAL
8- NORTH COVE
9- SOUTH COVE
10- PIER SITE
11- TIVOLI BAY

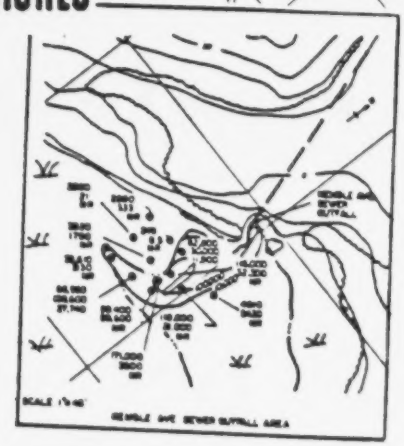
ACRES

COBALT CONCENTRATIONS IN SEDIMENTS

MARATHON BATTERY SITE Figure 8



ACRES



CONSTITUTION MARSH Cd AND Ni SURFACE SEDIMENT CONTOURS

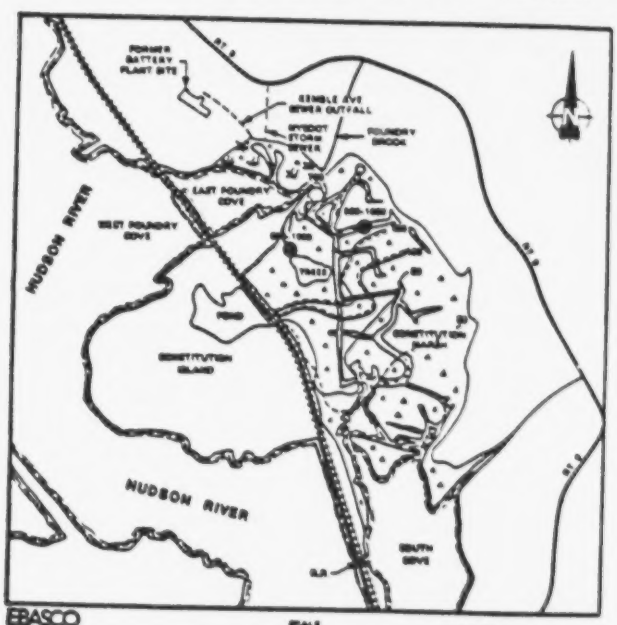
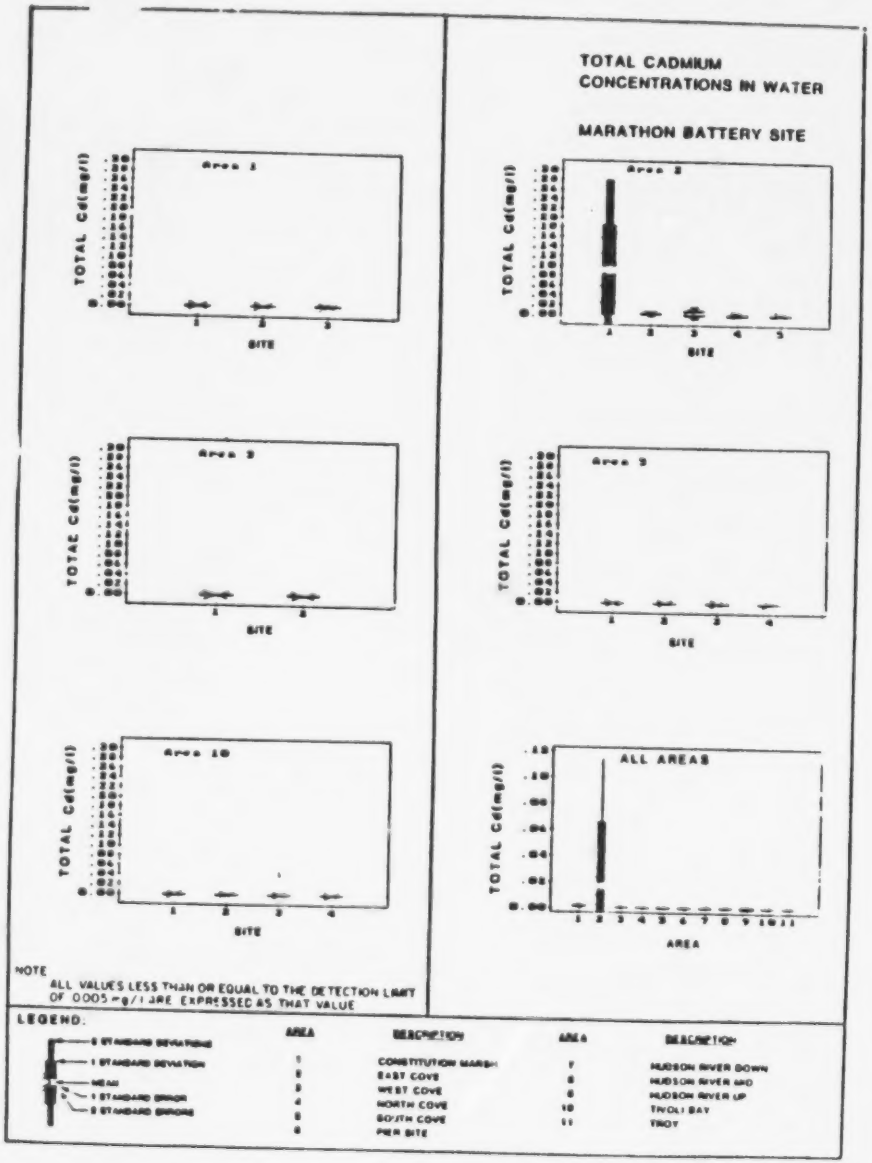
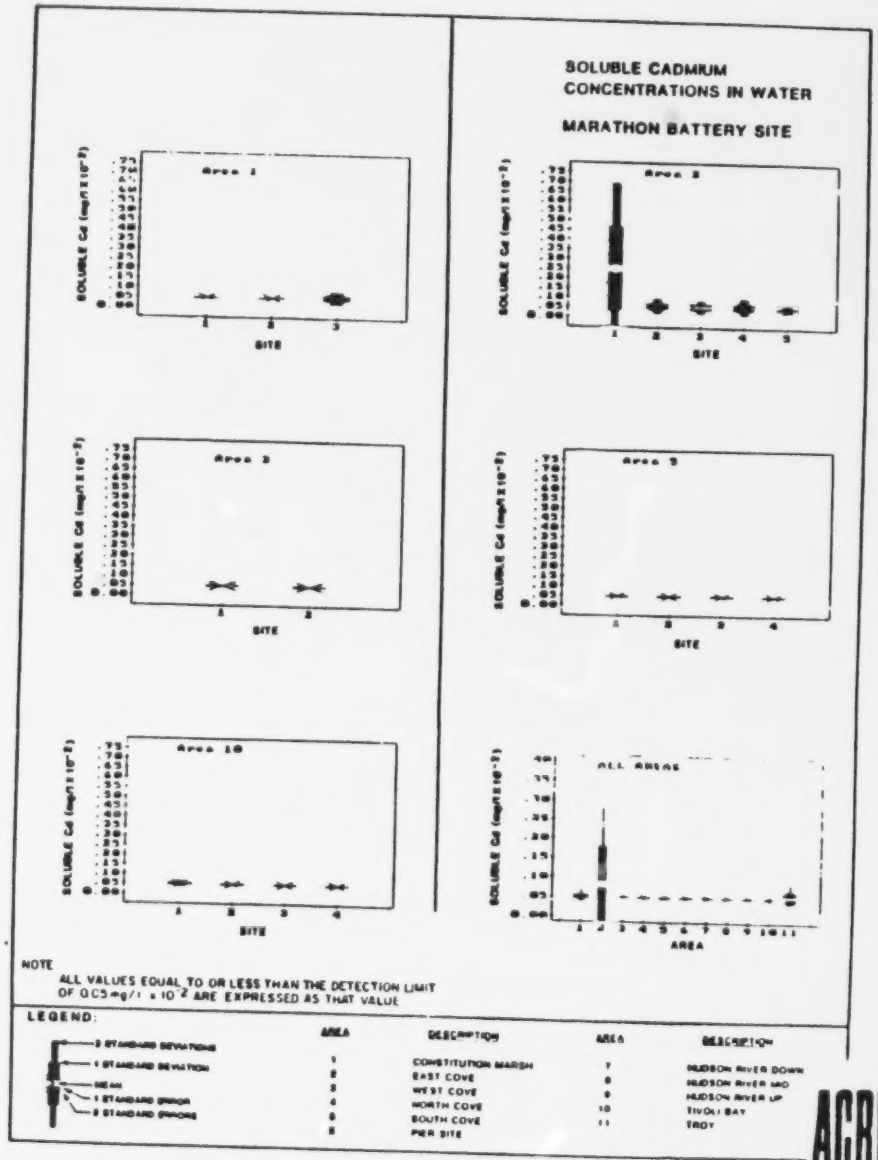


Figure 9



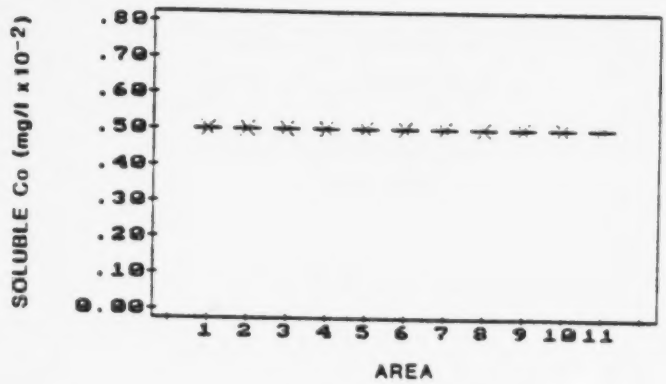


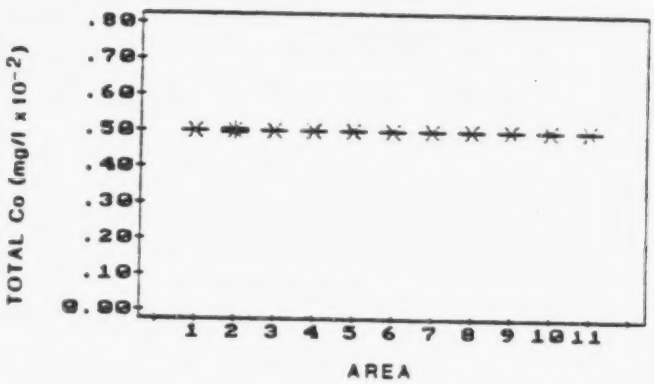
ACRES

Figure 10

SOLUBLE COBALT
AND TOTAL COBALT
CONCENTRATIONS IN WATER

MARATHON BATTERY SITE

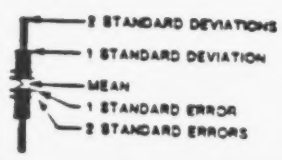




NOTE:
ALL VALUES EQUAL TO OR LESS THAN THE DETECTION LIMIT OF 0.50 mg/l x 10^{-2} ARE EXPRESSED AS THAT VALUE

ACRES

LEGEND:

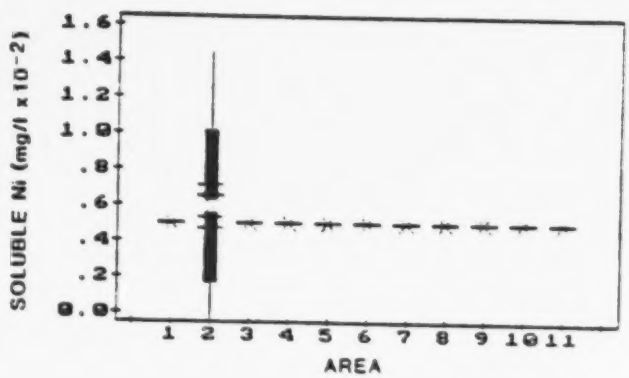


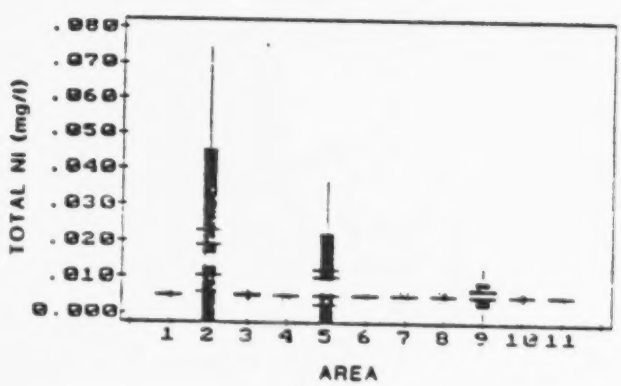
AREA	DESCRIPTION	AREA	DESCRIPTION
1	CONSTITUTION MARSH	7	HUDSON RIVER DOWN
2	EAST COVE	8	HUDSON RIVER MID
3	WEST COVE	9	HUDSON RIVER UP
4	NORTH COVE	10	TIVOLI BAY
5	SOUTH COVE	11	TROY
6	PIER SITE		

Figure 11

SOLUBLE NICKEL AND
TOTAL NICKEL
CONCENTRATIONS IN WATER

MARATHON BATTERY SITE

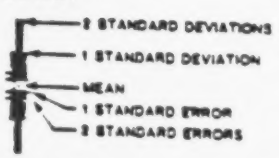




NOTE:
ALL VALUES EQUAL TO OR LESS THAN THE DETECTION LIMIT OF 0.005 mg/l ARE EXPRESSED AS THAT VALUE

ACRES

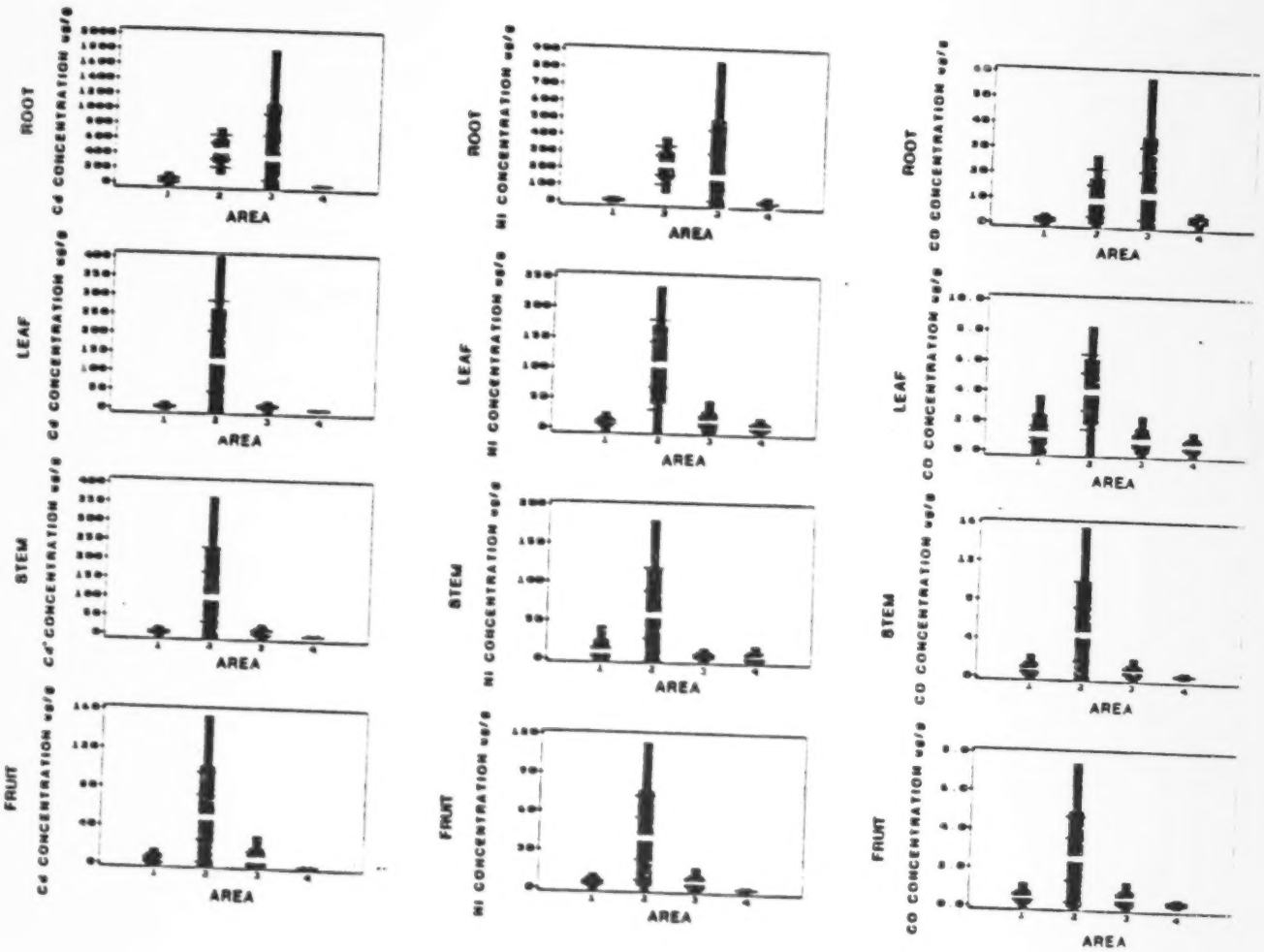
LEGEND:



AREA	DESCRIPTION	AREA	DESCRIPTION
1	CONSTITUTION MARSH	7	HUDSON RIVER DOWN
2	EAST COVE	8	HUDSON RIVER MID
3	WEST COVE	9	HUDSON RIVER UP
4	NORTH COVE	10	TIVOLI BAY
5	SOUTH COVE	11	TROY
6	PIER SITE		

Figure 12

WETLAND VEGETATION
CONCENTRATIONS



ACRES

NOTE: All data expressed as dry weight.

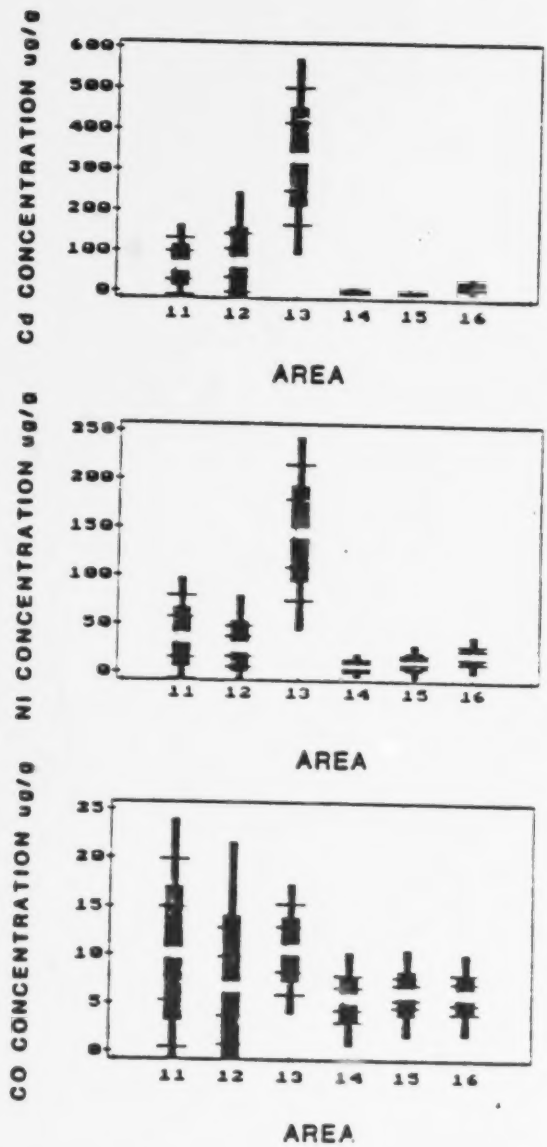
LEGEND

AREAS:

STATION 1 CONSTITUTION MARSH
2 EAST COVE OUTFALL
3 EAST COVE
4 TIVOLI BAY

Figure 13

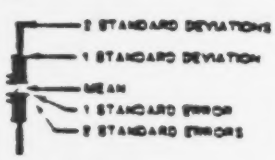
AQUATIC MACROPHYTES
WHOLE PLANT ANALYSIS



NOTE: All data expressed as dry weight.

ACRES

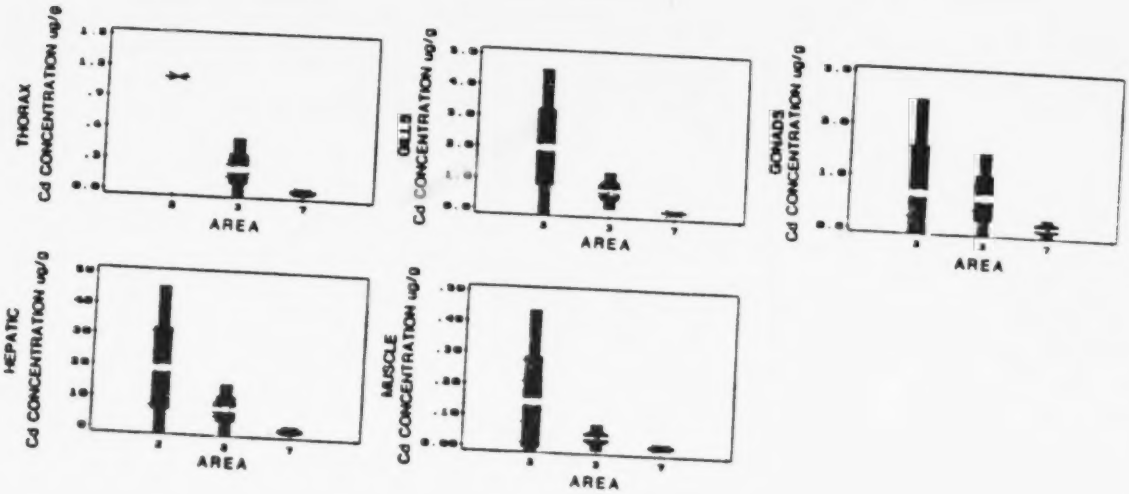
LEGEND:



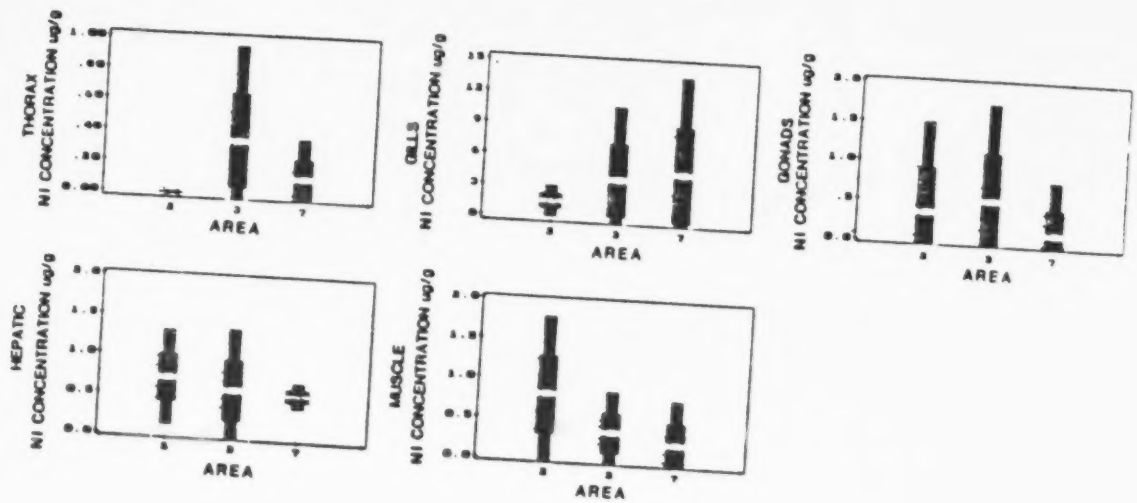
AREAS:
11 CONSTITUTION MARSH
12 EAST COVE
13 EAST COVE OUTFALL
14 SOUTH COVE
15 TIVOLI BAY
16 WEST COVE

Figure 14

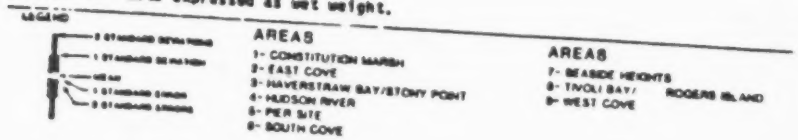
CADMIUM CONCENTRATIONS
MACROINVERTEBRATES



NICKEL CONCENTRATIONS
MACROINVERTEBRATES



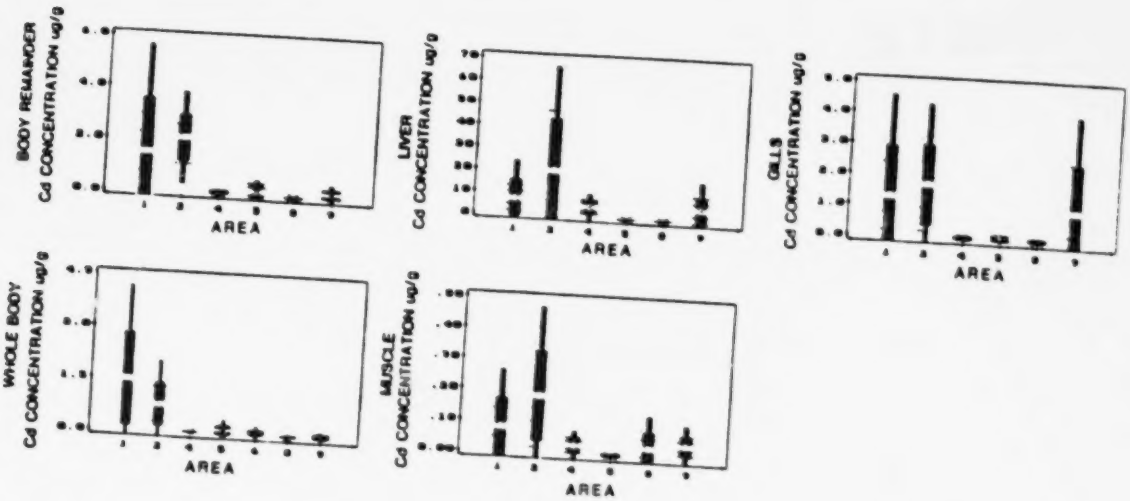
NOTE: All data expressed as wet weight.



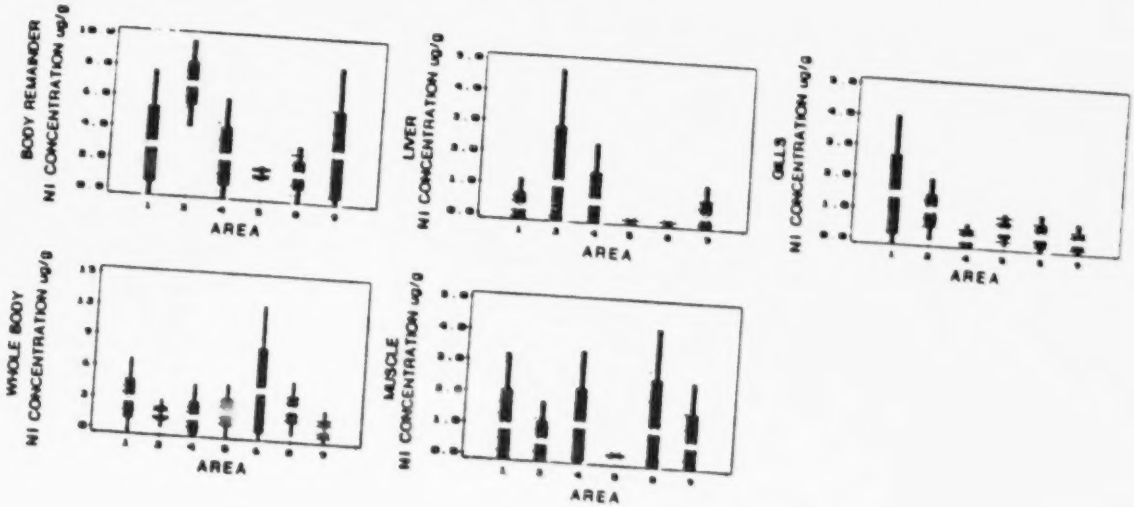
ACRES

Figure 15

CADMIUM CONCENTRATIONS
FISH



NICKEL CONCENTRATIONS
FISH



NOTE: All data expressed as wet weight.

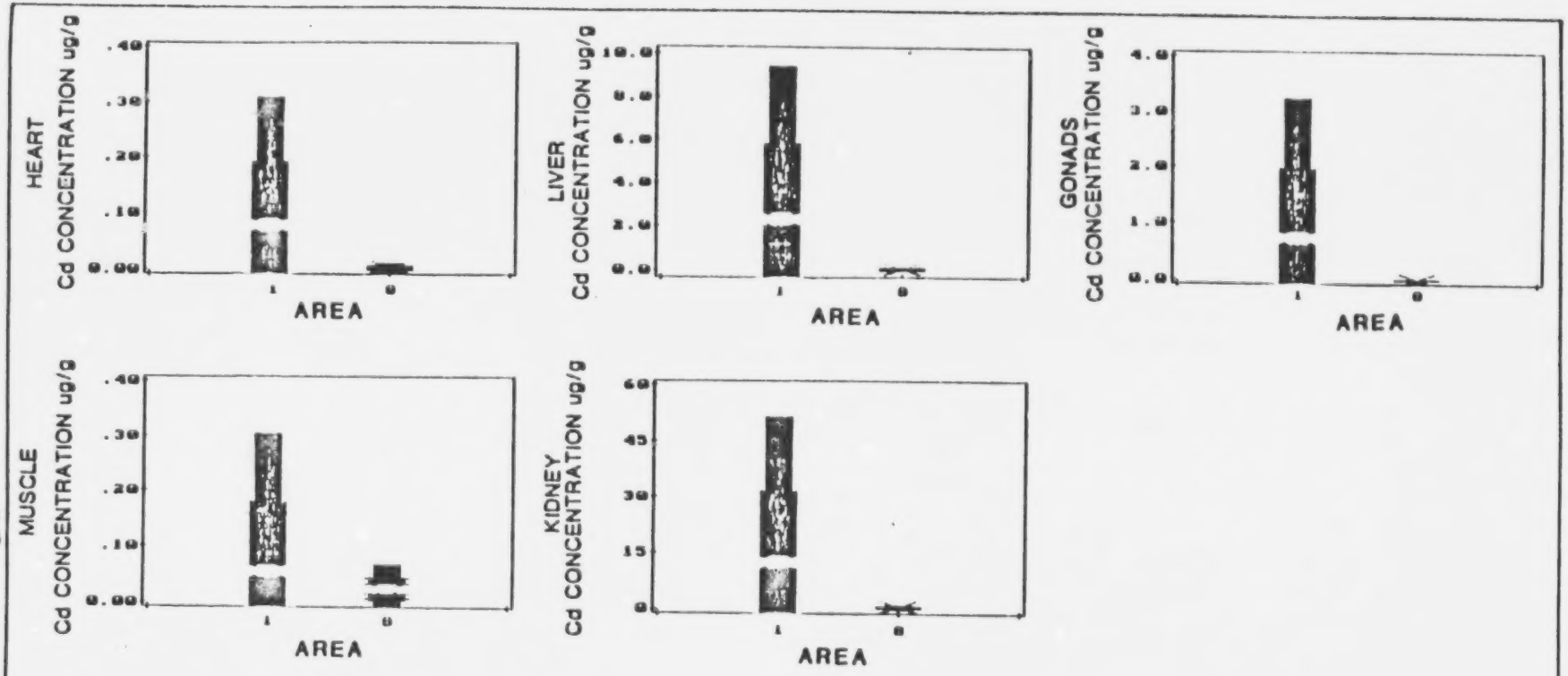
LEGEND

AREAS
1- CONSTITUTION MARSH
2- EAST COVE
3- HAVERSTRAW BAY/STONY POINT
4- HUDSON RIVER
5- PIER SITE
6- SOUTH COVE

AREAS
7- BEASIDE HEIGHTS
8- TIVOLI BAY/ ROGERS ISLAND
9- WEST COVE

ACRES

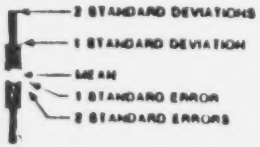
Figure 16



NOTE: All data expressed as wet weight.

ACRES

LEGEND



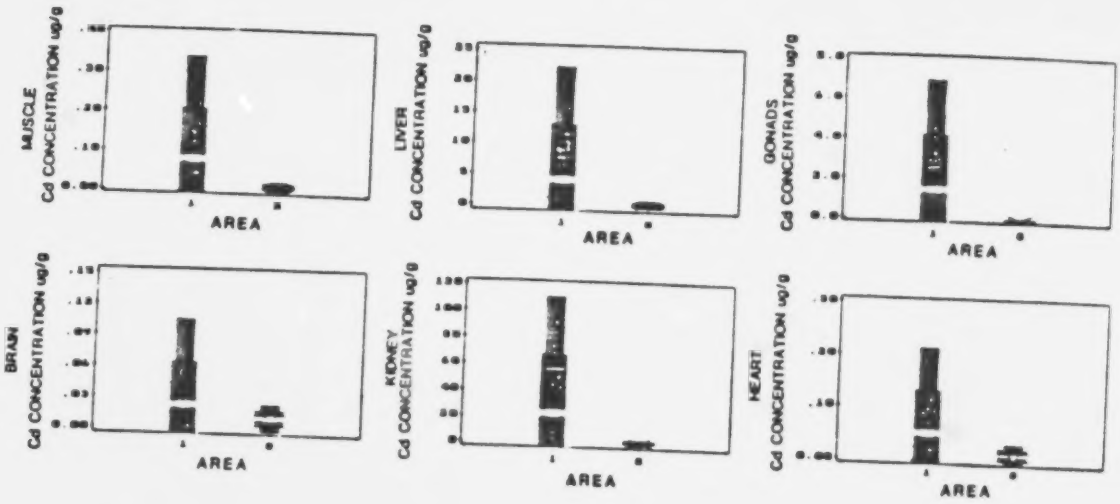
AREAS
1- CONSTITUTION MARSH
2- EAST COVE
3- HAVERSTRAW BAY/STONY POINT
4- HUDSON RIVER
5- PIER SITE
6- SOUTH COVE

AREAS
7- SEASIDE HEIGHTS
8- TIVOLI BAY/ ROGERS ISLAND
9- WEST COVE

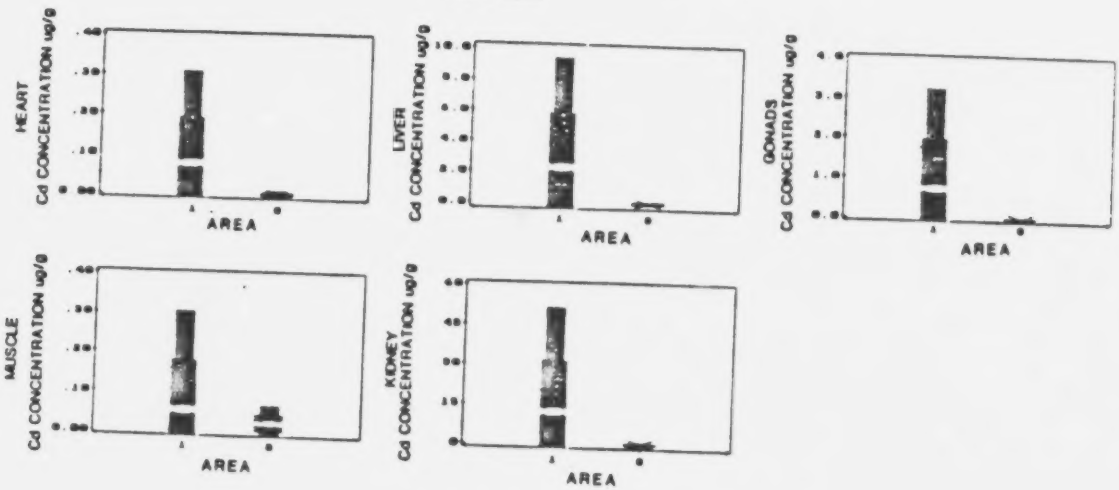
CADMIUM CONCENTRATIONS
REPTILES

Figure

CADMIUM CONCENTRATIONS
DUCKS



CADMIUM CONCENTRATIONS
REPTILES



NOTE: All data expressed as wet weight.

LEGEND

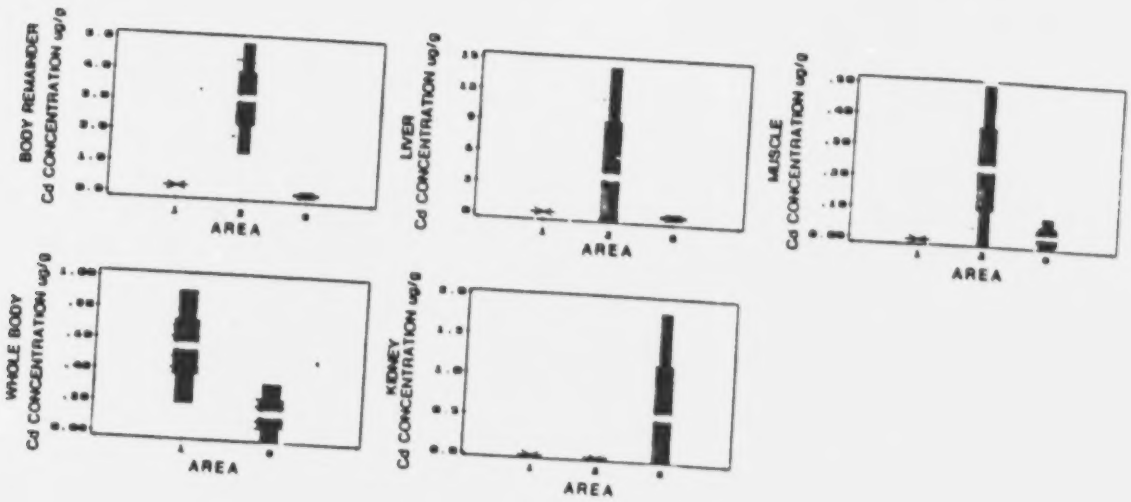
AREAS
1- CONSTITUTION MARSH
3- EAST COVE
3- HAVERSTRAW BAY/STONY POINT
4- HUDSON RIVER
5- PIER SITE
6- SOUTH COVE

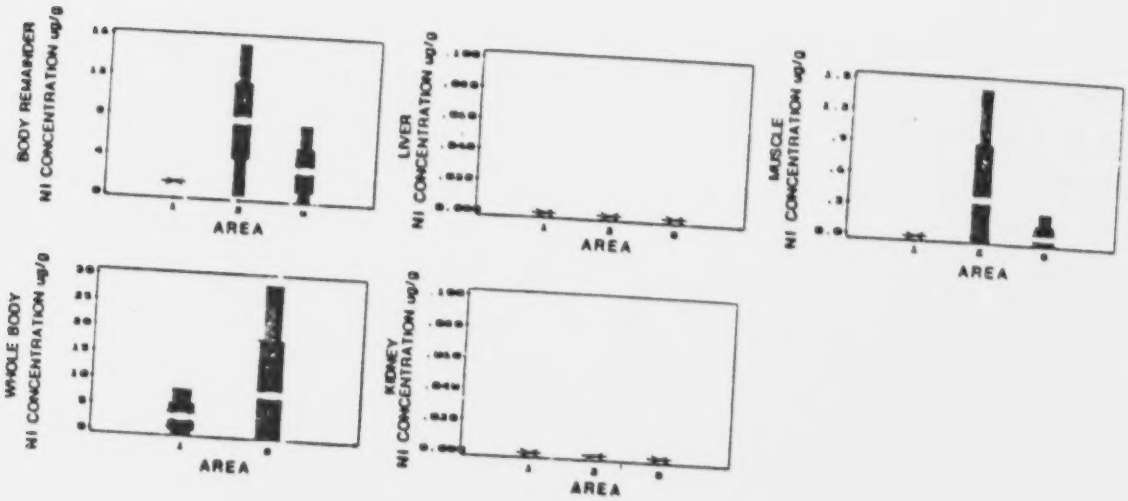
AREAS
7- SEASIDE HEIGHTS
8- TIVOLI BAY/ ROGERS ISLAND
9- WEST COVE

ACRES

Figure 18

BIRDS CONCENTRATIONS





NOTE: All data expressed as wet weight.

LEGEND

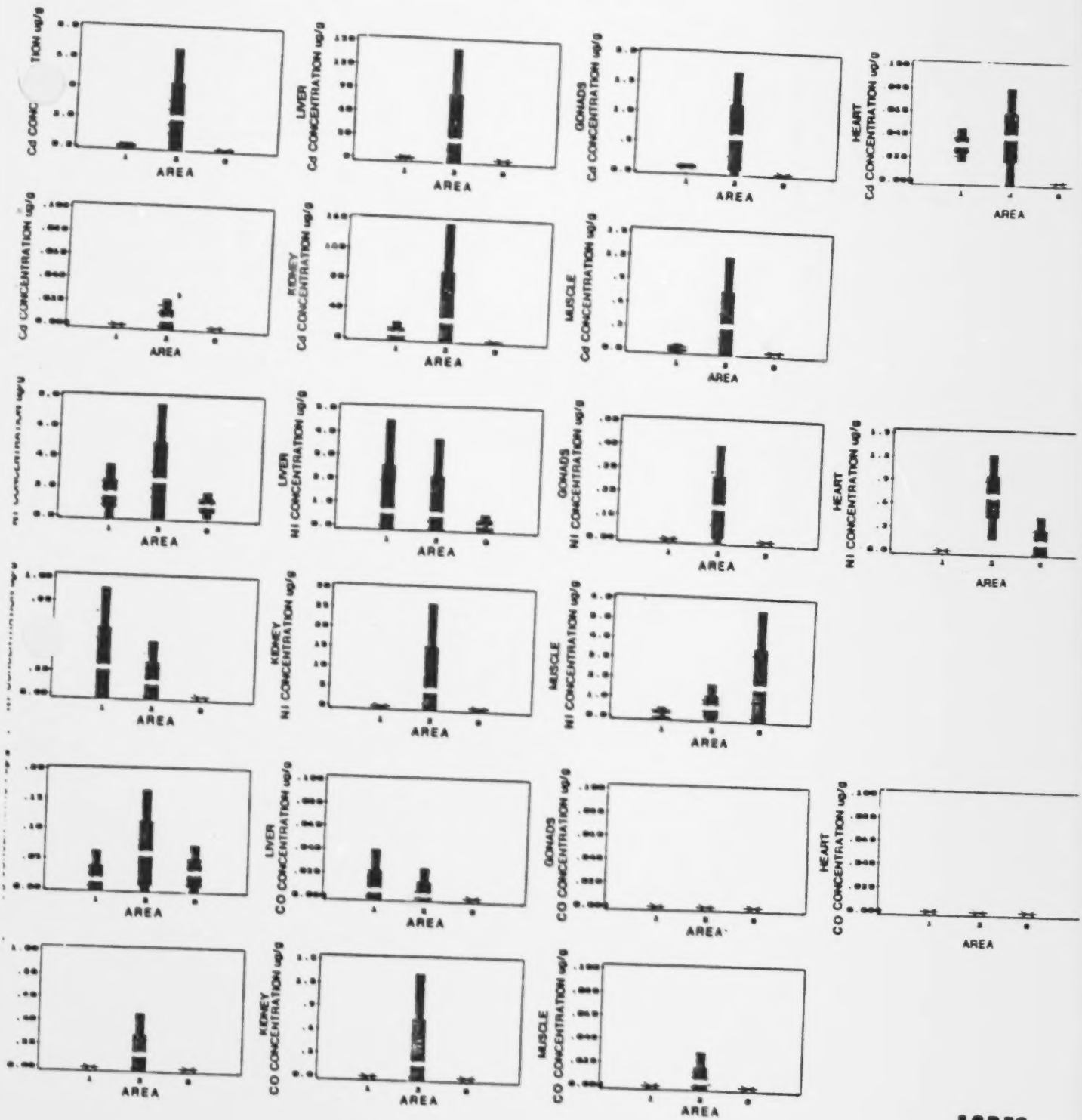
AREAS
1- CONSTITUTION MARSH
2- EAST COVE
3- HAVERSTRAW BAY/STONY POINT
4- HUDSON RIVER
5- PIER SITE
6- SOUTH COVE

AREAS
7- SEASIDE HEIGHTS
8- TYLOR BAY/ ROGERS ISLAND
9- WEST COVE

ACRES

Figure 19

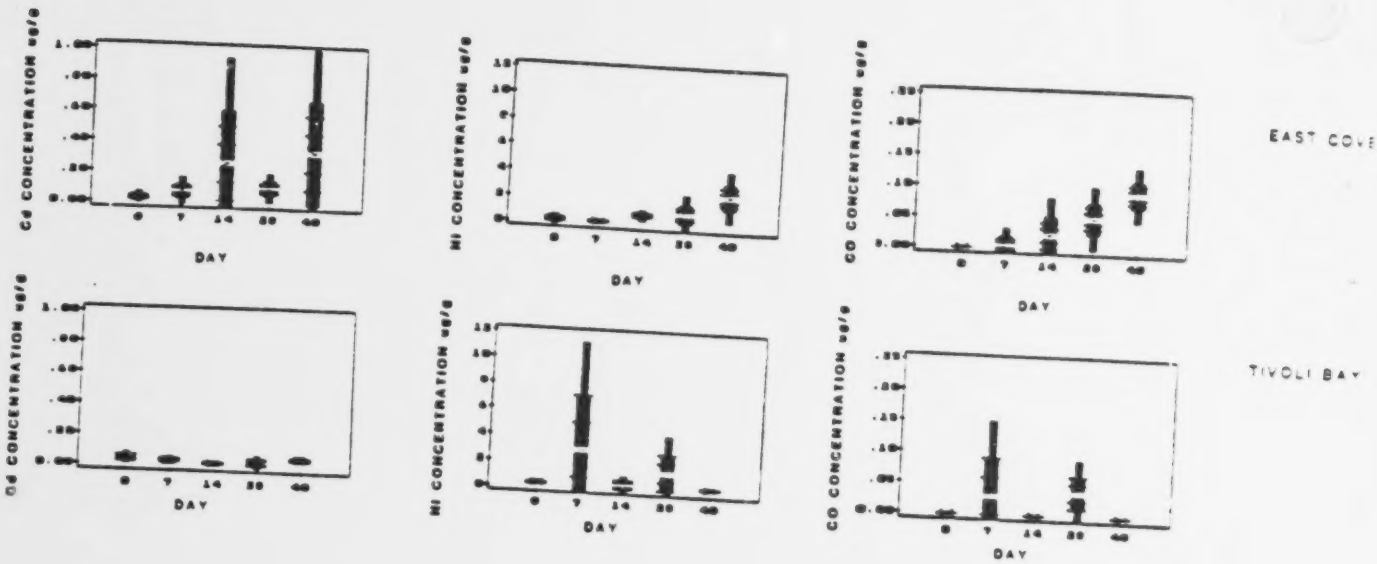
MAMMALS CONCENTRATIONS



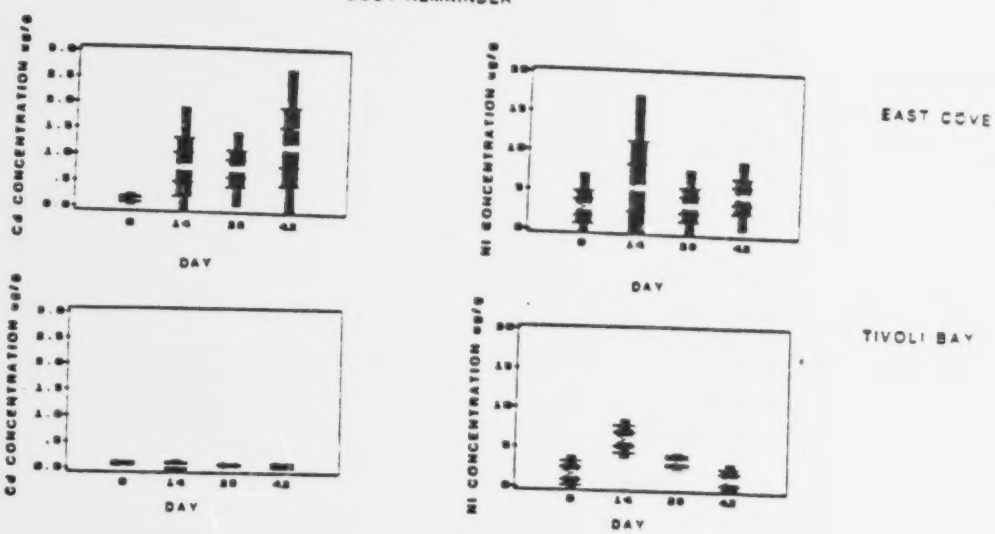
ACRES

Figure 20

BIOACCUMULATION STUDY
FUNDULUS HETEROCLITUS
BODY REMAINDER



BIOACCUMULATION STUDY
CAMBARUS IMMUIS
BODY REMAINDER



LEGEND

NOTE ALL VALUES EQUAL TO OR LESS THAN THE DETECTION LIMIT ARE EXPRESSED AS 0.00

NOTE: All data expressed as wet weight.

ACRES

Figure 21

Properties of Soils

Map Unit	USSCS Map Unit	Soil Name and Slope (%)	Parent Materials	Erodibility: Surface	Erodibility: Subsoil	Erodibility: Substratum	Hydrologic Group	Runoff Potential: w/ cover	Runoff Potential: w/o cover	Depth to Bedrock (m)	Depth to Seasonal Water Table (m)	Permeability (cm/sec): Subsoil	Permeability (cm/sec): Substratum
A	MeB	Merrimac Fine sandy loam 3-8	Glacial outwash	Med	Med	Low	A	Low	Med	2+	2+	1×10^{-3} to 1×10^{-2}	$>4 \times 10^{-3}$
B	MeC	8-15	Glacial outwash	Med	Med	Low	A	Low	Med	2+	2+	1×10^{-3} to 1×10^{-2}	$>4 \times 10^{-3}$
C	ChB	Charlton Fine sandy loam 2-8	Glacial till	Low	High	High	B	Low	Very high	2+	1+	4×10^{-4} to 4×10^{-3}	4×10^{-4} to 4×10^{-3}
D	ChC	8-15	Glacial till	Low	High	High	B	Low	Very high	2+	1+	4×10^{-4} to 4×10^{-3}	4×10^{-4} to 4×10^{-3}
E	ChD	15-25	Glacial till	Low	High	High	B	Med	Very high	2+	1+	4×10^{-4} to 4×10^{-3}	4×10^{-4} to 4×10^{-3}
F	HRC	Hollis-Rock Outcrop-Charlton 3-15											
		Hollis part	Glacial till	Med	High	—	D	High-very high	Very high	0.3-0.6	2+	1×10^{-3} to 4×10^{-3}	1×10^{-3} to 4×10^{-3}
		Rock outcrop part	Bedrock	—	—	—	D	Very high	Very high	0-0.3	2+	—	—
		Charlton part	Glacial till	Low	High	High	B	Low	Very high	2+	1+	4×10^{-4} to 4×10^{-3}	4×10^{-4} to 4×10^{-3}
G	SP	Sulfihemists, frequently		Essentially permanently flooded			D	Very high	Very high	—	0.5-0	—	—
H	UN	Urban Land	TOO VARIABLE TO CLASSIFY										

Source: Modified from USSCS, 1979.

Hydrologic Soil Groups

Hydrologic Group	Soil Series	Infiltration/Runoff Characteristics
A	A, B	Soils having high infiltration rates, even when thoroughly wetted; consisting chiefly of deep, well- to excessively drained sands or gravel or both. These soils have a high rate of water transmission and would result in a low runoff potential.
B	C, D, E, F	Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately coarse to medium textures. These soils have a moderate rate of water transmission.
C	None	Soils having slow infiltration rates when thoroughly wetted, consisting chiefly of (1) soils with a layer that impedes the downward movement of water, or (2) soils with moderately fine to fine textures and a slow infiltration rate. These soils have a slow rate of water transmission.
D	F, G	Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clay soils with a high swelling potential, (2) soils with a high permanent water table, (3) soils with a claypan or clay layer at or near the surface, and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

Source: Modified from USSCS, 1979.

CONCENTRATIONS IN SEDIMENT

SAMPLING STATION	CADMIUM			COBALT			NICKEL		
	UPPER CORE SEGMENT (mg/kg)	MIDDLE CORE SEGMENT (mg/kg)	BOTTOM CORE SEGMENT (mg/kg)	UPPER CORE SEGMENT (mg/kg)	MIDDLE CORE SEGMENT (mg/kg)	BOTTOM CORE SEGMENT (mg/kg)	UPPER CORE SEGMENT (mg/kg)	MIDDLE CORE SEGMENT (mg/kg)	BOTTOM CORE SEGMENT (mg/kg)
CMS1	700	8.4	1.2	28	9.2	11	420	18	20
CMS4	7.2	<1.0	1.4	<11	<10	<9.0	18	14	14
CMS6	370	20	---	43	16	---	420	58	---
CMS7	23	<0.47	---	10	9.7	---	23	20	---
CMS9	18	<0.35	---	8.6	4.9	---	27	13	---
ECHS1	4010	3420	---	162	198	---	2730	2340	---
ECHS2	110000	21000	---	3720	34	---	80200	3850	---
ECHS3	82900	130000	11900	2860	5410	---	54900	107000	---
ECHS4	116000	32300	---	3960	826	---	79400	19200	6790
ECHS5	99400	89400	---	3120	1420	---	58700	31600	---
ECHS6	249	8.3	---	16	4.8	---	374	14	---
ECHS7	3970	1780	---	193	22	---	3700	888	---
ECHS8	44940	139600	27740	1770	1250	---	40610	78850	---
ECHS9	2880	333	---	137	7.4	---	2310	183	10220
ECHS10	2800	21	---	78	4.8	---	1250	16	---
ECHS11	32610	3730	---	1120	64	---	22240	1800	---
ECSWA	171000	2500	---	6700	150	---	134000	3100	---
ECHS1	220	60	---	12	9.7	---	120	44	---
ECHS2	130	150	---	10	<10	---	120	87	---
ECHS3	220	8.3	---	13	<7.4	---	140	23	---
ECHS4	1900	190	---	88	10	---	1400	100	---
ECHS5	1400	190	1102	57	17	---	770	170	---
ECHS6	1200	150	---	53	22	---	730	140	---
ECHS7	420	28	8.0	34	15	---	250	44	---
ECHS8	70	13	---	<8.6	14	---	60	37	---
ECS1	3100	10400	---	160	260	---	3800	8500	---
ECS3	12100	3200	---	300	130	---	7200	3000	---
ECS4	2700	23	600	77	14	---	1300	31	---
ECS5	680	860	11	29	26	---	390	380	---
ECS6	850	1.9	2.0	1.9	13	8.0	2.4	32	---
ECS7	410	<0.39	2.4	25	13	---	230	32	---
ECS8	14	<0.34	0.62	20	14	---	34	12	---
ECS9	<0.29	<0.32	0.66	14	16	---	20	19	---
ECS10	280	1.6	<0.28	17	13	---	170	32	---
ECS11	460	4.1	0.57	27	13	---	200	22	---
ECS12	440	0.54	<0.28	30	19	---	120	12	---
ECS13	5.8	0.60	0.33	4.6	12	---	12	12	---
ECS14	67	---	---	<5.5	6.4	---	67	12	---
ECS15	39	2.2	---	8.0	2.1	---	34	12	---
ECS81	17	---	---	6.9	---	---	95	12	---
ECS82	140	102	1.9	17	16	---	71	12	---
ECS83	796	38	5.6	29	12	---	181	12	---
ECS84	7.0	0.33	<0.28	12	10	---	646	12	---
ECS85	712	14	2.1	22	15	---	34	12	---
ECS86	267	131	2.1	21	8.9	---	21	12	---
ECS87	315	2.8	1.2	24	13	---	1610	12	---
ECS88	814	3.8	1.1	30	14	---	43	12	---
ECS89	9.8	<0.43	<0.40	13	14	---	320	24	---
ECS810	36	4.9	0.89	16	13	---	26	18	---
ECS811	11	2.2	1.7	14	14	---	18	28	---
ECS812	3180	13	3.5	93	13	---	28	24	---
ECS813	35	5.8	1.3	13	16	---	20	20	---
TBS1	812	371	---	28	<9.3	---	18	11	---
TBS2	3.6	1.1	1.0	9.3	13	---	<9.8	24	---
TBS3	<0.28	<0.30	---	9.7	8.2	---	320	24	---
TBS8	<0.28	<0.28	<0.27	11	11	---	26	20	---
TBS9	2.7	0.54	0.57	13	14	---	18	11	---
	1.3	2.2	0.74	24	20	---	28	11	---
							0.36	11	---
							14	11	---

KEY: **AREA**

- CMS- CONSTITUTION MARSH SEDIMENT
- ECHS- EAST COVE HOT SPOT
- ECMS- EAST COVE MARSH SEDIMENT
- ECS- EAST COVE SEDIMENT
- ECSS- EAST COVE SUPPLEMENTAL SEDIMENT
- ECSWA- EAST COVE SEDIMENT WHITE AREA
- TBS- TIVOLI BAY SEDIMENT

ACRES

Table 3

SEDIMENT SAMPLES (CONSTITUTION MARSH UNLESS NOTED)

SAMPLE NUMBER	SAMPLE DEPTH (cm)	CADMIUM (mg/kg)	COBALT (mg/kg)	NICKEL (mg/kg)	SAMPLE DESCRIPTION	EH	PH	TEMP °C	% TOC	% SOLIDS
A1.01	0-10	120	20	120	GRAY BROWN CLAYEY SILT WITH PEAT				5.7	37.8
A1.02	40-50	4	17	33	GRAY BROWN SILTY CLAY WITH PEAT	-40	7.0	19	8.7	32.8
A1.02 DUPLICATE	40-50	5	19	19	GRAY BROWN SILTY CLAY WITH (45%) PEAT	+40	6.9		5.8	27.4
A1.03	80-90	*10	*10	26	GRAY BROWN CLAYEY SILT	+20	6.7		6.1	32.3
A2.01	0-10	230	20	190	DARK BROWN CLAYEY SILT	+50	7/3	18	6.7	36.1
A2.02	40-50				NOT RECOVERABLE	-	-	-	-	-
A2.03	80-90				NOT RECOVERABLE	-	-	-	-	-
B1.01	0-10	220	21	220	GRAY BROWN SILTY CLAY	+10	8.0	21	3.7	42.8
B1.01 DUPLICATE	0-10	230	26	230	GRAY BROWN SILTY CLAY	-20	7.4	21	4.0	43.9
B2.01	0-10	170	23	180	PEAT AND GRAY CLAYEY SILT	-30	7.3	17	6.9	32.5
B2.02	40-50				NOT RECOVERABLE	-	-	-	-	-
C1.01	t 0-10	140	16	120	GRAY SILTY CLAY	-52	6.7	27	4.7	38.0
C1.02	40-50	*8.3	17	37	GRAY SILTY CLAY	-50	7.0	24	3.3	48.0
C1.03	80-90	*13	13	40	DARK BROWN ORGANIC SILT	-140	6.8	25	3.7	30.0
C2.01	t 0-10	170	24	210	GRAY BROWN CLAYEY SILT	+280	7.3	21.5	7.4	33.0
C2.01 DUPLICATE	0-10	180	19	180	GRAY BROWN SILTY CLAY	+250	8.3	24	7.4	39.0
C2.02	40-50	*10	*13	42	PEAT AND GRAY CLAYEY SILT	-30	6.7	22.5	4.9	26.9
C2.03	70-80	41	*10	73	LOOSE WET PEAT	-20	7.7	21	9.8	19.3
C3.01	0-10	180	19	150	DARK GRAY CLAYEY SILT	+150	7.2	25	3.8	39.8
C3.02	40-50	8	17	44	DARK GRAY CLAYEY ORGANIC SILT (MUD)	-25	7.0	25	6.2	28.0
C3.03	80-90				NOT RECOVERABLE	-	-	-	-	-
C4.01	0-10	170	20	150	DARK GRAY CLAYEY SILT	-430	8.4	20.5	3.6	37.9
C4.02	40-50	*3	5	19	DARK GRAY CLAYEY SILT AND RHIZOMES	+100	6.8	19	12.0	29.0
C4.03	80-90				NOT RECOVERABLE	-	-	-	-	-
D1.01	0-10	150	13	100	DARK BROWN CLAYEY SILT	+300	6.6	24	5.4	41.5
D2.01	0-10	940	44	660	GRAY, SILTY CLAY, MOIST	-54	6.8	24	9.8	32.8
D2.02	40-50				NOT RECOVERABLE	-	-	-	-	-
D2.03	80-90				NOT RECOVERABLE	-	-	-	-	-
D3.01	0-10	320	28	370	PEAT AND GRAY BROWN SILT	-70	7.4	24	4.2	35.7
D4.01	0-10	69	15	84	PEAT AND CLAYEY SILT	+50	7.7	25	9.5	35.9
D4.02	40-50				NOT RECOVERABLE	-	-	-	-	-
D4.03	80-90				NOT RECOVERABLE	-	-	-	-	-
D5.01	0-10	270	31	360	GRAY BROWN CLAYEY SILT	+100	6.8	24	2.1	-
D6.01	0-10	170	23	160	GRAY BROWN HIGHLY ORGANIC CLAYEY SILT	+280	6.8	30	5.5	43.0
D6.02	40-50	19	*19	48	DARK BROWN TO BLACK CLAYEY ORGANIC SILT	+200	6.6	27	6.7	21.0
D6.03	80-90				NOT RECOVERABLE	-	-	-	-	-
D7.01	0-10	170	17	160	DARK BROWN HIGHLY ORGANIC CLAYEY SILT	+290	7.2	-	3.0	-
D8.01	t 0-10	100	*20	100	DARK BROWN ORGANIC SILT	-35	6.8	-	4.9	-
D8.02	40-55	*25	*25	*25	GRAY CLAYEY SILT; PEAT BOTTOM 5CM	-60	6.6	-	4.8	-
D8.03					NOT RECOVERABLE	-	-	-	-	-
E1.01	0-10	200	20	160	GRAY CLAYEY SILT AND PEAT	+110	7.1	22	6.5	27.7
E1.02	40-50				NOT RECOVERABLE	-	-	-	-	-
E1.03	80-90				NOT RECOVERABLE	-	-	-	-	-
E3.01	0-10	180	18	160	GRAY BROWN CLAYEY SILT	+110	6.9	25	3.8	43.0

* ACTUAL CONCENTRATION IS LESS THAN NUMBER SHOWN.
t BENCH SCALE TEST

EBASCO

SEDIMENT SAMPLES (CONSTITUTION MARSH UNLESS NOTED)

SAMPLE NUMBER	SAMPLE DEPTH (cm)	CADMIUM (mg/kg)	COBALT (mg/kg)	NICKEL (mg/kg)	SAMPLE DESCRIPTION	EH	PH	TEMP °C	% TOC	% SOLIDS
E3.02	40-50	11	11	27	DARK BROWN CLAYEY SILT AND PEAT	+70	6.3	23	6.2	37.0
E4.01	0-10	170	18	110	GRAY BROWN CLAYEY SILT AND PEAT	+110	6.8	26	8.7	28.0
E5.01	0-10	300	25	230	DARK BROWN ORGANIC CLAYEY SILT	+100	6.7	27	7.3	32.0
E5.02	40-50				NOT RECOVERABLE	-	-	-	-	-
E5.03	80-90				NOT RECOVERABLE	-	-	-	-	-
F1.01	0-10	270	27	230	DARK BROWN TO BLACK FINE TO MEDIUM SAND	-220	7.9	22	22.0	29.0
F3.01	t 0-10	370	32	350	GRAY BROWN CLAYEY SILT	+150	7.0	-	2.7	31.0
F4.01	0-10	200	24	220	GRAY CLAYEY SILT	+35	6.8	35	6.1	41.0
F4.02	40-50	*27	*27	*27	DARK BROWN CLAYEY SILT AND PEAT	+20	6.7	27	9.3	15.0
F5.01	0-10	91	12	100	DARK BROWN ORGANIC CLAYEY SILT	-80	7.1	25.5	4.8	33.0
G1.01	0-10	160	11	110	DARK BROWN ORGANIC SILT AND PEAT	-100	6.8	19	7.8	17.0
G1.02	40-50				NOT RECOVERABLE	-	-	-	-	-
G1.03	80-90				NOT RECOVERABLE	-	-	-	-	-
G2.01	0-10	93	4	60	PEAT MATTED VEGETATION	+90	7.7	21	8.9	6.5
G3.01	0-10	260	21	300	GRAY BROWN CLAYEY SILT TO SILTY CLAY, ORGANICS	+30	6.8	19	6.2	38.0
G4.01**	0-10	9	25	56	DARK BROWN CLAYEY SILT	+25	6.5	-	4.8	28.1
G4.02**	40-50	230	28	360	DARK BROWN CLAYEY SILTS WITH ORGANICS	+180	7.8	20	8.9	42.3
G5.01	0-10	200	20	130	DARK BROWN TO BLACK CLAYEY SILT WITH PEAT	-100	6.2	-	5.3	34.9
G6.01	0-10	140	22	230	GRAY BROWN SILTY CLAY AND PEAT	-30	7.8	21	5.5	39.3
G7.01	0-10	440	40	680	GRAY SILTY CLAY, SOME PEAT (25%)	-220	6.9	20.5	5.8	40.0
G8.01	0-10	90	18	100	GRAY BROWN SILTY CLAY, SOME RHIZOMES	-160	6.6	20.5	5.0	31.0
G8.02	36-44	*9	*23	*9	DARK BROWN PEAT	-70	7.7	19	22.0	16.0
H1.01	0-10	210	27	220	GRAY BROWN TO DARK BROWN CLAYEY SILT	+60	6.9	19	4.1	43.0
H1.02	40-50	*10	15	45	GRAY BROWN SILTY CLAY SOME PEAT (30%)	+60	5.9	19	13.0	36.1
H2.01	0-10	230	23	220	GRAY BROWN SILTY CLAY	+10	6.9	22	3.9	41.0
H3.01	0-10	380	31	300	GRAY BROWN SILTY CLAY	-10	6.45	20.5	6.0	39.0
H3.02	40-50	18	13	36	GRAY BROWN SILTY CLAY	+10	7.0	19.5	9.2	36.0
H4.01	0-10	13	*7	38	BLACK ORGANIC SILT, SOME PEAT (25%)	-	-	-	65.0	15.0
H4.02	40-50				NOT RECOVERABLE	+30	8.0	22.5	-	-
H5.01	0-10	290	21	180	GRAY BROWN CLAY SILT	+230	6.9	18	5.2	42.1
H6.01	0-10	170	19	140	GRAY BROWN SILTY CLAY WITH RHIZOMES	-	-	-	3.4	41.0
H6.02	40-50				NOT RECOVERABLE	-150	6.7	22	-	-
H7.01	0-10	140	19	120	GRAY BROWN SILTY CLAY	-90	7.5	22	7.2	39.0
H8.01	0-10	8	11	27	GRAY BROWN SILTY CLAY, LITTLE RHIZOMES	-115	7.8	18	5.5	62.7
I1.01	0-10	29	*10	57	BROWN ORGANICS - MATTED VEGETATION	-50	8.7	17	3.1	9.4
I2.01	0-10	32	*9	46	BROWN ORGANICS - MATTED VEGETATION SOME SILT	-	-	-	11.0	9.1
I2.02	40-50				NOT RECOVERABLE	-30	7.5	20	-	-
I3.01	0-10	110	11	100	PEAT AND SOME BROWN SILT (65/35)	+80	7.5	22	6.7	28.0
I4.01	0-4	98	13	120	BROWN SILT	-	-	-	7.5	29.0
I4.02	40-50				NOT RECOVERABLE				-	-

* ACTUAL CONCENTRATION IS LESS THAN NUMBER SHOWN.
t BENCH SCALE TEST
** POSSIBLE REVERSAL OF G4.01 AND G4.02 BECAUSE OF SAMPLING, PACKAGING OR ANALYTICAL ERROR

EBASCO

Table 4

SEDIMENT SAMPLES (CONSTITUTION MARSH UNLESS NOTED)

SAMPLE NUMBER	SAMPLE DEPTH (cm)	CADMIUM (mg/kg)	COBALT (mg/kg)	NICKEL (mg/kg)	SAMPLE DESCRIPTION	EH	PH	TEMP °C	% TOC	% SOLIDS
I5.01	0-10	70	17	86	GRAY BROWN CLAYEY SILT	+110	7.7	23	3.8	44.0
I5.01 DUPLICATE	0-10	200	22	160	GRAY BROWN SILT, SLIGHTLY CLAYEY, SOME RHIZOMES	-50	7.2	22.5	4.1	43.2
I6.01	0-10	91	17	110	GRAY BROWN CLAYEY SILT	-30	6.8	24	7.2	33.4
I6.02	40-50	*5	*5	10	DARK BROWN TO BLACK PEAT SOME CLAYEY SILT	-10	6.8	23	6.1	20.0
I7.01	0-4	200	14	150	PEAT WITH DARK BROWN SILT (75/25)	-100	7.4	24	5.2	29.0
I8.01	0-3	230	*28	130	MATTED BROWN PEAT	-70	7.1	22	6.9	13.4
I8.02	40-50				NOT RECOVERABLE	-	-	-	-	-
I9.01	0-10	13	11	45	GRAY BROWN SILTY CLAY, LITTLE RHIZOMES	-50	7.5	20.5	6.5	32.9
I10.01	0-10	*10	*10	43	GRAY BROWN PLASTIC SILTY CLAY, SOME RHIZOMES	-150	7.3	22	4.5	39.7
J1.01	0-10	18	*9	36	BROWN ORGANICS - CATTAIL LEAVES, RHIZOMES	+300	8.3	14	4.5	8.2
J2.01	0-10	47	*9	75	BROWN ORGANICS - MATTED VEGETATION	+60	7.6	16	7.0	9.1
J2.02	40-50				NOT RECOVERABLE	-	-	-	-	-
J3.01	0-10	4	4	33	GRAY BROWN SILTY CLAY, SITTLE RHIZOME	+220	7.3	22	12.0	35.9
J4.01	0-10	*9	17	43	GRAY BROWN SILTY CLAY MOIST	-220	7.8	23	5.3	43.3
J4.02	40-50	7	10	32	GRAY BROWN SILTY CLAY (25% PEAT)	-130	7.4	21	5.3	33.4
J4.02 DUPLICATE	40-50	7	7	33	GRAY BROWN SILTY CLAY (30% PEAT)	-70	7.2	22	4.8	55.0
K1.01	0-10	56	21	49	DARK BROWN ORGANIC SILT, SATURATED	-200	7.4	22	5.6	26.6
K1.01 DUPLICATE	0-10	57	17	57	DARK BROWN ORGANIC SILT	-200	7.4	22	5.6	24.1
K2.01	t 0-10	83	12	77	GRAY BROWN CLAYEY SILT	+80	7.9	-	2.4	31.0
K2.02	40-50	16	7	42	GRAY BROWN SILT CLAY (20% PEAT)	-180	6.5	23	3.2	37.4
K2.03	80-90	*4	10	13	DARK GRAY BROWN PLASTIC CLAY, SOME ORGANICS	-150	6.8	21	3.0	54.5
K3.01	0-10	13	13	35	GRAY SILTY CLAY, LITTLE PEAT (15%)	-400	-	20	6.4	44.8
K4.01	0-10	*10	*10	15	BROWN PEAT, SOME GRAY CLAYEY SILT (20%)	-210	-	17	11.0	38.8
K4.02	40-50	-	-	-	BROWN PEAT, SOME GRAY CLAYEY SILT (30%)	-190	-	19	6.0	-
K5.01	0-10	14	14	33	GRAY BROWN CLAY, LITTLE PEAT (15%)	-	-	18.5	8.4	41.5
L1.01	0-10	13	17	35	DARK GRAY BROWN CLAYEY SILT MOIST	-130	-	19.5	6.4	42.4
L2.01	0-10	18	13	35	BROWN TO GRAY SILTY CLAY, LITTLE RHIZOMES	-	-	19	7.3	44.7
L2.01 DUPLICATE	0-10	12	12	38	GRAY SILTY CLAY		-	19	10.0	42.0
L3.01	0-10	13	13	34	GRAY BROWN SILTY CLAY, SOME PEAT (30%)	-	-	19.5	5.0	43.3
M1.01	0-10	170	20	160	GRAY BROWN SILTY CLAY AND PEAT (50/50)	+70	6.1	23	5.7	34.2
M1.02	40-50	7	*5	14	DARK BRAY TO BLACK PEAT WITH CLAYEY SILT	-120	6.5	22.5	4.9	17.0
M2.01	0-10	530	53	660	GRAY BROWN SILT CLAY	+120	6.7	21	5.4	41.6
M3.01	0-10	510	34	550	PEAT AND GRAY BROWN SILTY CLAY (50/50)	+110	6.8	20.5	5.0	40.0
M3.02	40-50	*11	*6	44	BROWN PEAT WITH CLAYEY SILT (20%)	-120	6.5	23	4.7	17.0
M4.01	0-10	280	15	160	BROWN TO BLACK ORGANIC SILT, LITTLE PEAT	-270	7.1	20	4.3	16.1
M5.01	0-10	220	25	210	GRAY BROWN SILTY CLAY	-80	6.4	24	5.9	43.1
M6.01	0-10	150	21	170	GRAY BROWN SILTY CLAY	+50	6.2	22	3.8	40.0
M7.01	0-10	900	99	1600	PEAT AND CLAYEY SILT (50/50)	-20	6.2	22	6.3	39.7

* ACTUAL CONCENTRATION IS LESS THAN NUMBER SHOWN.
t BENCH SCALE TEST

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Table 4
Continued

SEDIMENT SAMPLES (CONSTITUTION MARSH UNLESS NOTED)

SAMPLE NUMBER	SAMPLE DEPTH (cm)	CADMIUM (mg/kg)	COBALT (mg/kg)	NICKEL (mg/kg)	SAMPLE DESCRIPTION	EH	PH	TEMP °C	% TOC	% SOLIDS
CP-1.01	0-10	*6	36	60	BLACK ORGANIC SILT	-290	7.0	20	8.2	15.9
CP-1.02	40-50				NOT RECOVERABLE	-	-	-	-	-
CP-2.01	0-10	*6	13	25	GRAY BROWN CLAY	-100	6.75	21	1.5	59.0
CP-3.01	0-10	17	17	66	DARK BROWN TO BLACK ORGANIC SILT	-120	6.5	20	6.7	9.3
CP-3.02	40-50				NOT RECOVERABLE	-	-	-	-	-
CP-3.01 DUPLICATE	0-10	9	*4	22	DARK BROWN TO BLACK ORGANIC SILT	-130	6.5	19	9.0	10.6
1-EAST COVE	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
2-EAST COVE	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
3-EAST COVE	t 0-10				VERY SOFT BROWN ORGANIC MUD, SOME SAND	-200	8.0	17	-	-
	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
4-EAST COVE	t 0-10				DARK BROWN PEAT AND CLAYEY SILT	+190	7.8	18	-	-
	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
5-EAST COVE	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
6-EAST COVE	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
7-EAST COVE	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
8-EAST COVE	t 0-10				GRAY BROWN CLAYEY SILT (to 15CM)	-85	7.7	22.5	-	-
	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
9-EAST COVE	t 0-10				PEAT WITH DARK BROWN SILTY CLAY (35%)	-	-	-	-	-
	50-60				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
10-EAST COVE	t 0-10				VERY WET, DARK GRAY BROWN ORGANIC SILT	-230	8.0	21	-	-
	40-50				NOT RECOVERABLE	-	-	-	-	-
	80-90				NOT RECOVERABLE	-	-	-	-	-
MA-CM	t SURFACE				YELLOWISH WATER	-	-	-	-	-
MA EAST COVE(1-4)	t SURFACE				YELLOWISH WATER	-	-	21	-	-

* ACTUAL CONCENTRATION IS LESS THAN NUMBER SHOWN.
t BENCH SCALE TEST

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Table 4
Continued

COMPOSITE WATER SAMPLES FROM
EAST COVE TRESTLE - OCTOBER 25, 1984

Tide Stage		Cd Concentration (mg/l) Top	Bottom
High Slack	1	<0.0005	0.0006
Ebb	1	0.0018	0.0021
Low Slack	1	0.0013	0.0016
Flood	1	<0.0005	<0.0005
High Slack	2	<0.0005	<0.0005
Ebb	2	0.0026	0.0024
Low Slack	2	0.0050	0.0061

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Table 5

PRIORITY POLLUTANT
SEDIMENT

INORGANIC ANALYSIS

mg/g

	Ag	As	Be	Cr	Cu	Ni
Tivoli Bay	0.79	24	<0.41	386	85	0.94
South Cove	<0.66	24	<0.65	33	172	0.16
Hudson River	1.2	23	<0.45	131	72	0.64
East Cove	0.76	23	<0.97	105	105	0.95
West Cove	1.1	23	<0.59	130	93	0.62

	Pb	Sb	Se	Tl	Sn
Tivoli Bay	116	<2.1	<2.1	<2.1	299
South Cove	226	<3.2	<3.3	<3.3	110
Hudson River	92	<2.2	<2.3	<2.3	233
East Cove	165	<4.9	<5.0	<5.0	202
West Cove	109	<2.9	<2.9	<2.9	253

	Tivoli Bay	E. Cove
PESTICIDES mg/g		
aldrin	ND	ND
dieldrin	ND	ND
chlordane	ND	ND
4,4'-DDT	ND	ND
4,4'-DDE	ND	ND
4,4'-DDD	ND	ND
alpha-endosulfan	ND	ND
beta-endosulfan	ND	ND
endosulfan sulfate	ND	ND
endrin	ND	ND
endrin aldehyde	ND	ND
heptachlor	ND	ND
heptachlor epoxide	ND	ND
alpha-BHC	ND	ND
beta-BHC	ND	ND
gamma-BHC	ND	ND
delta-BHC	ND	ND
PCB-1242	ND	ND
PCB-1254	1.7	0.4
PCB-1221	ND	ND
PCB-1232	ND	ND
PCB-1248	0.8	2.0
PCB-1260	ND	ND
PCB-1016	ND	ND
toxaphene	ND	ND

ND = Was detected at or above reporting limit of 0.3

	Tivoli Bay	E. Cove
BASE/NEUTRAL COMPOUNDS		
fluoranthene	*	*
4-chlorophenyl phenyl ether	ND	ND
4-bromophenyl phenyl ether	ND	ND
bis(2-chloroisopropyl)ether	ND	ND
bis(2-chloroethoxy)methane	ND	ND
hexachlorobutadiene	ND	ND
hexachlorocyclopentadiene	ND	ND
isophorone	ND	ND
naphthalene	*	ND
nitrobenzene	ND	ND
N-nitrosodimethylamine	ND	ND
N-nitrosodiphenylamine	ND	ND
N-nitrosodi-n-propylamine	ND	ND
bis(2-ethylhexyl)phthalate	580	*
butyl benzyl phthalate	ND	ND
di-n-butyl phthalate	*	ND
di-n-octyl phthalate	ND	ND
diethyl phthalate	ND	ND
dimethyl phthalate	ND	ND
benzo(a)anthracene	*	*
benzo(a)pyrene	ND	*
3,4-benzofluoranthene	**	**
benzo(k)fluoranthene)		
chrysene	*	*
acenaphthylene	ND	ND
anthracene	ND	ND
benzo(ghi)perylene	ND	ND
fluorene	ND	ND
phenanthrene	*	*
dibenzo(a,h)anthracene	ND	ND
indeno(1,2,3-cd)pyrene	ND	ND
pyrene	*	*
2,3,7,8-tetrachlorodibenzo-p-dioxin	ND	ND

	Tivoli Bay	E. Cove
VOLATILE ORGANICS ug/g		
Chloromethane	ND	ND
Bromomethane	ND	ND
Vinyl chloride	ND	ND
Chloroethane	ND	ND
Methylene chloride	ND	ND
Acetone	ND	ND
Carbon disulfide	ND	ND
1,1-dichloroethene	ND	ND
1,1-dichloroethane	ND	ND
Trans-1,2-dichloroethene	ND	ND
Chloroform	ND	ND
1,2-dichloroethane	ND	ND
2-Butanone	ND	ND
1,1,1-trichloroethane	ND	ND
Carbon tetrachloride	ND	ND
Vinyl acetate	ND	ND
Bromodichloromethane	ND	ND
1,2-dichloropropane	ND	ND
Trans-1,3-dichloropropene	ND	ND
Trichloroethene	ND	ND
Dibromochloromethane	ND	ND
1,1,2-trichloroethane	ND	ND
Benzene	ND	ND
Cis-1,3-dichloropropene	ND	ND
2-Chloroethylvinylether	ND	ND
Bromoform	ND	ND
2-Hexanone	ND	ND
4-Methyl-2-pentanone	ND	ND
Tetrachloroethene	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND
Toluene	ND	ND
Chlorobenzene	ND	ND
Ethylbenzene	ND	ND
Styrene	ND	ND
Total xylenes	ND	ND

	Tivoli Bay	E. Cove
ACID COMPOUNDS ug/kg		
2,4,6-trichlorophenol	ND	ND
p-chloro-m-cresol	ND	ND
2-chlorophenol	ND	ND
2,4-dichlorophenol	ND	ND
2,4-dimethylphenol	ND	ND
2-nitrophenol	ND	ND
4-nitrophenol	ND	ND
2,4-dinitrophenol	ND	ND
4,6-dinitro-o-cresol	ND	ND
pentachlorophenol	ND	ND
phenol	ND	ND
BASE/NEUTRAL COMPOUNDS ug/kg		
acenaphthene	ND	ND
benzidine	ND	ND
1,2,4-trichlorobenzene	ND	ND
hexachlorobenzene	ND	ND
hexachloroethane	ND	ND
bis(2-chloroethyl)ether	ND	ND
2-chloronaphthalene	ND	ND
1,2-dichlorobenzene	ND	ND
1,3-dichlorobenzene	ND	ND
1,4-dichlorobenzene	ND	ND
3,3-dichlorobenzidine	ND	ND
2,4-dinitrotoluene	ND	ND
2,6-dinitrotoluene	ND	ND
1,2-diphenylhydrazine	ND	ND

ND = None detected above the average reporting limit of 510 ppb for acids and for B/N.

*Trace concentrations detected below the average reporting limit.

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Table 6

METAL CONCENTRATIONS IN BENTHIC INFAUNA AND CORRESPONDING SEDIMENT CONCENTRATIONS

Benthic Infauna Sampling Site	Benthic Infauna Metal Concentrations (ug/g wet weight)			Corresponding or Adjacent Sediment Site	Surficial Sediment Metal Concentrations (mg/kg dry weight)		
	Cd	Co	Ni		Cd	Co	Ni
ECBS-1	570	18	400	EC'S 1	5100	160	3800
ECBS-2	11	<17	<31	EC'S 3	2700	77	1300
ECBS-3	6.8	0.68	4.4	EC'S 8	<0.29	14	20
ECBS-4	50	2.0	20	EC'S 10	460	27	200
CMBS-1	13	1.5	18	CMS 9	18	8.6	27
CMBS-2	5.7	0.61	4.9	CMS 7	23	10	25
CMBS-3	18	1.9	21	CMS 1	700	28	420
TBBS-1	2.9	<0.2	39	TBS-1	3.6	9.5	26
TBBS-2	0.35	<0.48	1.9	TBS-2	<0.28	9.7	18
TBBS-3	0.41	2.1	5.7	TBS-3	<0.28	11	28

Notes: EC = East Cove

CM = Constitution Marsh

TB = Tivoli Bay

ACRES

Table 1

METAL CONCENTRATIONS IN BENTHIC ALGAE

Area	Station	Date	Cadmium	Nickel	Cobalt
East Cove	ECBA-1	Aug 22	2,840	2,200	120
	ECBA-2	July 18	97	130	22
	ECBA-3	June 15	5.1	13	2.6
		July 18	40	200	28
		Aug 22	48	93	8.0
	ECBA-4	June 18	6.2	33	6.4
Average East Cove Concentrations			306	439	31
Tivoli Bay	TBBA-1	June 13	1.9	35	26
		July 19	1.3	31	16
		Aug 23	2.0	30	15
	TBBA-2	July 19	4.3	63	23
		Aug 23	1.9	22	5.7
	TBBA-3	Aug 23	0.48	25	5.6
Average Tivoli Bay Concentrations			2.0	35	15

Notes: 1. All data expressed as ug/g wet weight.

METAL CONCENTRATIONS IN ZOOPLANKTON

Area	Station	Date	Cadmium	Nickel	Cobalt
East Cove	ECP-1	Aug 24	140	70	9.3
		Oct 25	870	490	19
	ECP-2	June 15	430	81	5.2
		July 18	33	75	4.0
		Aug 24	130	64	6.9
		Oct 25	99	81	7.9
	ECP-3	July 18	880	240	17
Average East Cove Concentrations			342	151	10
Hudson River	HUP	June 14	0.22	2.4	0.51
Prior Site	PSP	June 14	3.8	21	1.8
		Aug 22	63	58	<9.3
		Oct 25	17	29	5.3
Average Prior Site Concentrations			28	36	3.7
South Cove	SCP	June 15	2.1	15	2.9
		July 18	7.7	42	<10
		Oct 25	1.3	50	8.9
Average South Cove Concentrations			7.6	36	5.9
Tivoli Bay	TBP-1	June 13	<.47	20	<8.7
		June 21	1.8	50	6.1
		July 19	5.8	29	6.3
		Aug 23	2.7	16	2.7
		Oct 24	1.7	35	6.0
	TBP-2	June 21	2.2	130	3.8
		July 19	4.2	18	6.3
		Aug 23	1.5	18	5.7
		Oct 24	5.8	33	8.0
Average Tivoli Bay Concentrations			3.2	39	5.6
West Cove	WCP	June 14	6.8	4.3	0.60
		Aug 22	72	83	<3.8
		Oct 25	20	34	1.9
Average West Cove Concentrations			33	40	2.2

Notes: 1. All data expressed as ug/g wet weight.
2. All values less than the detection limit were not included in the calculation of averages.

METAL CONCENTRATIONS IN PHYTOPLANKTON

Area	Station	Date	Cadmium	Nickel	Cobalt
East Cove	ECP-1	July 18	310	200	27
		Aug 24	301	240	<14
	ECP-2	June 15	5.1	48	4.1
		July 18	69	110	9.9
		Oct 25	240	35	8.3
Average East Cove Concentrations			205	127	11.8
Hudson River	HUP	June 14	0.22	2.4	0.51
		Aug 24	67	13	4.9
	HDP	Aug 24	17	96	<7.7
Average Hudson River Concentrations			28	37	2.7
Prior Site	PSP	June 14	1.8	22	3.3
South Cove	SCP	June 15	1.4	41	3.1
		July 18	32	70	6.0
		Aug 24	82	180	14
Average South Cove Concentrations			34	97	7.7
Tivoli Bay	TBP-1	June 13	0.07	48	11
		June 21	0.59	37	<5.8
		July 19	1.9	63	3.8
		Oct 24	3.7	80	10
	TBP-2	June 21	2.5	97	88
		July 19	0.32	33	13
Average Tivoli Bay Concentrations			1.7	66	25
West Cove	WCP	Oct 25	31	620	32

NOTES: 1. All data expressed as ug/g wet weight.
2. All values less than the detection limit were not included in the calculation of averages.

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Table 8

CADMIUM AND NICKEL CONCENTRATIONS OF FISH MUSCLE, BODY REMAINDER
GILL AND LIVER TISSUES (µg/g wet weight)

Area	Species	# Sample	Muscle Range Cd	Muscle Range Ni	Body Remainder Range Cd	Body Remainder Range Ni	Gills Range Cd	Gills Range Ni	Liver Range Cd	Liver Range Ni
EC	Morone americana	2	0.200 -0.320	<0.130 -1.200	1.100 -2.600	5.400 -8.000	1.700 -3.00	1.300	9.400-47.00	<2.000- 3.200
EC	Lepomis gibbosus	1	0.034	0.330	2.600	7.500	0.420	0.460	4.900	<0.720
CH	Micropterus salmoides	1	0.0022	0.590	—	—	0.053	3.600	0.088	0.700
CH	Morone americana	4	0.0079-0.280	0.130 -1.200	0.063 -2.200	1.100 -8.000	0.097 -3.000	0.420 -2.400	3.300-25.00	0.260- 1.200
CH	Lepomis gibbosus	2	0.011 -0.057	1.300 -3.800	0.037 -0.870	1.700 -3.800	0.024 -4.800	0.310 -3.100	3.200-3.800	<0.350-<1.600
CH	Notemigonus crysoleucas	2	0.070 -0.170	0.160 -0.390	0.990 -6.300	0.740 -4.300	0.480 -0.510	0.520 -1.900	3.500	<0.87
WC	Morone americana	3	0.0097-0.0620	<0.057 -2.100	0.056 -0.270	1.300 -7.100	0.110 -3.300	<0.48 -0.48	0.059-14.00	<1.200- 0.980
WC	Lepomis gibbosus	1	0.075	0.160	0.400	1.500	0.340	0.500	4.400	<0.860
PS	Acipenser oxyrhynchus	1	0.0067	0.180	0.330	1.600	0.039	0.320	0.110	<0.200
PS	Lepomis gibbosus	1	0.0023	0.170	0.380	1.300	0.120	0.680	0.130	<0.420
HU	Morone americana	2	0.023 -0.055	0.730 -2.400	0.039 -0.150	2.300 -4.400	<0.180 -0.091	0.430 -<3.700	1.900-7.500	<0.840-<11.00
HD	Morone americana	1	0.014	0.150	0.079	0.790	0.055	<0.170	4.900	1.600
TB	Notemigonus crysoleucas	2	0.0032-0.0880	0.043 -2.900	0.032*	0.840*	<0.017 -0.055	<0.340 -0.560	0.160	<0.500
TB	Lepomis gibbosus	1	0.0018	0.120	0.014	2.100	0.083	0.590	0.061	<0.290

Note:
*1 sample

FISH WHOLE BODY HEAVY METAL CONCENTRATIONS (µg/g wet weight)

Area	Species	# Samples	Range Cd	Range Ni
East Cove (EC)	Morone saxatilis	1	0.640	1.500
EC	Lepomis gibbosus	1	0.510	2.800
EC	Notropis hudsonius	1	1.500	1.700
EC	Fundulus heteroclitus	1	1.600	1.500
EC	Fundulus diaphanus	2	0.095-0.440	0.830-1.400
Constitution Marsh (CM)	Lepomis macrochirus	1	1.400	2.600
CM	Alosa pseudoharengus	1	4.300	7.200
CM	Fundulus heteroclitus	1	3.200	4.900
CM	Fundulus diaphanus	4	0.110-1.500	1.000-2.600
CM	Notropis hudsonius	3	0.140-2.500	1.100-3.700
CM	Anguilla rostrata	1	0.270	3.800
West Cove (WC)	Morone saxatilis	1	0.063	0.630
WC	Microgadus tomcod	1	0.015	0.130
WC	Notropis hudsonius	1	0.130	0.720
Pier Site (PS)	Morone americana	2	0.160-0.400	1.300-3.100
PS	Microgadus tomcod	2	0.042-0.084	0.350-1.100
PS	Fundulus diaphanus	1	0.034	1.100
PS	Notropis hudsonius	1	0.069	2.500
South Cove (SC)	Morone americana	2	0.0055-0.1900	0.059-3.600
SC	Notemigonus crysoleucas	1	0.210	2.700
SC	Lepomis gibbosus	1	0.100	2.100
SC	Fundulus diaphanus	2	0.050-0.051	2.100-4.600
SC	Fundulus heteroclitus	1	0.100	15.000
SC	Notropis hudsonius	3	0.065-0.250	2.800-5.400
Hudson Up (HU)	Microgadus tomcod	1	0.015	1.100
HU	Morone americana	1	0.049	1.100
HU	Notropis hudsonius	3	0.044-0.072	0.410-4.500
Hudson Down (HD)	Morone saxatilis	1	0.068	0.320
HD	Microgadus tomcod	1	0.045	0.390
HD	Morone americana	2	0.059-0.067	0.470-1.600
HD	Notropis hudsonius	1	0.068	0.460
Tivoli Bay (TB)	Morone americana	1	0.044	3.900
TB	Lepomis gibbosus	1	0.0079	2.400
TB	Fundulus diaphanus	2	0.024-0.049	1.600-4.100
TB	Fundulus heteroclitus	1	0.059	1.400

ACRES

CADMIUM CONCENTRATIONS IN MACROINVERTEBRATE (Callinectes sapidus) TISSUES
(ug/g wet weight)

Location	Sample Size (n)	Hepatopancreas			Thoracic Muscle			Claw/Leg Muscle			Gills			Gonads		
		Range			Range			Range			Range			Range		
		Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
East Cove	5	39.0	7.00	19.4	1.10*	1.10*	1.10*	0.400	0.041	0.167	3.50	0.660	2.00	2.00	0.220	0.710
Harveystraw Bay	6	16.0	5.30	9.5	0.450	0.160	0.260	0.086	0.024	0.045	1.40	0.490	0.850	1.60	0.089	0.620
Stony Point	6	7.80	1.90	4.5	0.520	0.053	0.201	0.042	0.020	0.029	0.700	0.447	0.560	1.20	0.490	0.690
Seaside Heights	6	1.90	0.300	0.87	0.050	0.015	0.026	0.019	0.006	0.013	0.100	0.029	0.071	0.260	0.044	0.117

Note: *Only 1 (one) thoracic muscle tissue sample was analyzed for East Cove.

Cadmium Concentrations in Snapping Turtles (Chelydra Serpentina)

Area	Sample Size (n)	Tissue														
		Liver			Kidney			Heart			Muscle			Gonads		
		Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Constitution Marsh	6	9.40	0.310	2.33	52.00	1.90	12.40	.310	.0049	0.077	.3100	.0020	.0369	3.20	.0063	.720
East Cove	1	23.00	23.00	23.00	27.00	27.00	27.00	0.25	0.25	0.25	.060	.060	.060	0.530	0.530	0.530
Tivoli Bay	5*	.130	0.0330	0.0602	1.10	0.220	0.588	.0460	.0023	.0131	.0590	.0035	.0255	.0076	.0023	0.0051

Note: * Gonad Sample Size (n) = 4

RANGE OF CADMIUM CONCENTRATIONS IN MAMMALS

Species/Area	Liver			Kidneys			Carcass			Body Remainder		
	Sample Size (n)	Max.	Min.	Sample Size (n)	Max.	Min.	Sample Size (n)	Max.	Min.	Sample Size (n)	Max.	Min.
Muskrat												
East Cove (EC)	(2)	2.60	1.20	(2)	15.0	4.10	(2)	0.480	0.120	---	---	---
Constitution Marsh (CM)	(2)	2.60	2.20	(2)	17.0	9.20	(1)	0.082	0.082	---	---	---
Tivoli Bay Area/Rudgers Island (TB/RI)	(5)	0.065	0.007	(5)	0.370	0.020	(3)	ND	ND	---	---	---
White-footed Mouse												
EC	(14)	14.0	0.100	(3)	4.10	0.019	---	---	---	(14)	2.40	0.076
CM	(6)	0.420	0.065	(1)	0.194	0.194	---	---	---	(6)	0.246	0.025
TB	(6)	0.290	0.032	(1)	0.210	0.210	---	---	---	(6)	0.041	0.002
Norway Rat												
EC	(3)	270.	14.0	(3)	210.	2.30	(1)	1.20	1.20	(2)	4.10	2.80
CM	(1)	0.380	0.380	(1)	2.0	2.00	(1)	0.100	0.100	---	---	---
TB	---	---	---	---	---	---	---	---	---	---	---	---
Water Shrew												
EC	(2)	77.0	42.1	(2)	12.0	8.574	---	---	---	(2)	9.70	4.90
CM	---	---	---	---	---	---	---	---	---	---	---	---
TB	---	---	---	---	---	---	---	---	---	---	---	---

Note: All data expressed as ug/g wet weight.
ND - Not detectable

ACRES

FEASIBLE GENERAL RESPONSE ACTIONS AND ASSOCIATED REMEDIAL TECHNOLOGIES

GENERAL RESPONSE ACTIONS	TECHNOLOGY CATEGORIES
NO ACTION	MONITORING, RESTRICTED ACCESS, PUBLIC AWARENESS
CONTAINMENT	CAPPING, SEDIMENT DISPERSON CONTROL
HYDRAULIC CONTROL	TIDAL, RUNOFF
COMPLETE REMOVAL	DREDGING, EXCAVATION
PARTIAL REMOVAL	DREDGING, EXCAVATION
ON-SITE TREATMENT	THERMAL, CHEMICAL, AND PHYSICAL TREATMENT
OFF-SITE TREATMENT	THERMAL, CHEMICAL, AND PHYSICAL TREATMENT
INSITU TREATMENT	CHEMICAL AND PHYSICAL TREATMENT
ON-SITE DISPOSAL	LANDFILL (HAZARDOUS OR NON-HAZARDOUS)
OFF-SITE DISPOSAL	LANDFILL (HAZARDOUS OR NON-HAZARDOUS), OCEAN DISPOSAL
TRANSPORTATION	TRUCK, TRAIN, BARGE, PIPELINE
SITE RESTORATION	MARSH REVEGETATION

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Table 1)

SUMMARY TABLE OF REMEDIAL TECHNOLOGIES

Technology	Possible - Further Evaluation Required	Eliminated from Further Evaluation
1. No Action	X	
2. Containment		
A. Capping	X	
• Clay cap		X
• Synthetic membrane		X
• Stone/gravel	X[a]	
• Filter Fabric	X[a]	
• Chemical Sealants		X
• Armorform	X[a]	
• Clean Sediment	X[a]	
• Multimedia	X	
B. Sediment Dispersion Control		
• Silt Curtains	X	
• Dikes	X	
• Freezing		X
• Sheet Piling	X	
3. Hydraulic Control		
A. Tidal Control		
• Dikes	X	
• Pumping	X[a]	
B. Runoff Control		
• Ditches	X	
4. Removal		
A. Excavation	X[a]	
• Backhoe	X[a]	
• Bulldozer		X
• Front End Loader		X
• Dragline		X
B. Mechanical Dredging		X
C. Hydraulic Dredging	X	
• Suction/Dustpan		X
• Cutterhead		X
• Hopper Dredge		X
• Horizontal Auger-Cutter	X	
• Pneumatic Dredging		X
5. On-Site or Off-Site Treatment		
A. Thermal (Incineration)		X
B. Chemical Treatment	X	
• Acidification		X
• Extraction/Recovery		X
• Fixation	X	
• Precipitation/ Flocculation		X
• Biodegradation		X
• Activated Carbon		X

Technology	Possible - Further Evaluation Required	Eliminated from Further Evaluation
C. Physical Treatment		
• Drying Beds		X
• Gravity Thickener	X	
• Sedimentation Basins	X	
• Dehydro Drying Beds	X	
• Ultrasonic Dewatering		X
• Centrifuge		X
• Filter Press (Plate & Frame)		X
• Belt Filter Press	X	
• Vacuum Filter	X	
• Clarification	X	
• Filtration	X	
6. In-Situ Treatment		
A. Chemical		
• Extraction		X
• Grout Injection		X
B. Physical		
• Vitrification		X
7. Disposal		
A. Disposal as Hazardous Waste		
• Construct On-site RCRA Landfill	X	
• Construct Off-Site RCRA Landfill		X
• Use Existing RCRA Landfill	X	
B. Disposal as Non-Hazardous Waste		
• Construct On-Site Landfill	X	
• Construct Off-Site Landfill		X
• Use Existing Sanitary Landfill	X	
• Ocean Disposal		X
8. Transportation		
A. Truck	X	
B. Train		X
C. Barge		X
D. Pipeline	X[a]	
9. Site Restoration		
• Marsh Revegetation	X	

[a] To be considered in combination with other technologies.

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Table 12

Comparison of Alternatives Considered to NCP Requirements

Alternative	No Action	Attains ARAR	Exceeds ARAR	Offsite Disposal	Reduces Threat
ECM-1	X				
ECM-2		X	X[a]	X	
ECM-3		X	X[a]		
ECM-4		X	X	X	
ECM-5					X
CM-1	X				
CM-2		X	X[a]	X	
CM-3		X	X[a]	X	
CM-4		X	X[a]		X
CM-5					

[a] Depending on the performance of the dredging operations and treatment and disposal facility.

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Table 13

DRAFT FEASIBILITY STUDY REPORT
SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

Remedial Alternative	Cost ($Million) Capital	Present Worth	Public Health Concerns	Environmental Concerns	Technical Concerns	Institutional Concerns	Other Concerns	Time To Implement
EC-1 No Action	0.25	0.25	• Minimal worker risk. • Continued potential for direct contact with contaminated sediments. • Continued resuspension and redistribution of contaminated sediments.	• High potential-contaminated sediment remains at site. • Continued migration of metals to other waterbodies and wetlands. • High potential for continued bioaccumulation and toxic effects on aquatic and wetland biota.	• Minimal	• Toxic metals not removed.	• Exposure to contaminated sediments from recreational uses. • Detrimental effect on wildlife. • Impact on property values.	1 month
EC-2 Hydraulic Dredging Thickening Filtration Offsite Disposal	36.63	39.13	• Major worker risk • Possible traffic accidents causing public exposure. • Maximizes direct contact with contaminated sediments. • Minimizes resuspension, redistribution of contaminated sediments.	• Removes highly contaminated sediment. • Eliminates migration of metals. • Prevents contaminated aquatic fauna exposure. • Eliminates toxic effect on wetland biota. • Possible to restore 12.5 acres of marsh.	• High effectiveness. • Heavy construction traffic. • Proven technology.	• Consumes off-site sanitary landfill capacity.	• Truck traffic through the town. • Restoration of marsh may take longer than anticipated.	3 years
EC-3 Hydraulic Dredging Thickening Filtration On-Site Disposal	25.88	28.38	• Same as EC-2	• Same as EC-2	• High effectiveness. • Proven technology, land is available. • Site not adequate for Construction Marsh or Area II.		• Location of RCRA Landfill on-site in the vicinity of a residential area. • Restoration of marsh may take longer than anticipated. • Acquisition of land for on-site landfill may be difficult.	3 years
EC-4 Hydraulic Dredging Thickening Dewatering Off-Site Disposal	21.42	23.53	• Same as EC-2	• Same as EC-2	• Same as EC-2	• Consumes Offsite Hazardous Waste Landfill Capacity	• Same as in EC-2.	3 years
EC-5 Containment	9.58	11.95	• Moderate worker risk.	• Contains high metal-contaminated sediment at site. • Uncertain in long-term elimination of migration of metals and toxic effects to biota. • Possible to recreate 12.5 acres of marsh elsewhere. • Minor change of flow pattern.	• New technology. • Unproven design.	• Potential exists for contaminated material to escape, since toxic materials not removed.	• Potential loss of 12.5 acres of marsh.	27 months

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Table 14

CONSTITUTION MARSH
SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

Remedial Alternative	Cost ($Million) Capital	Present Worth	Public Health Concerns	Environmental Concerns	Technical Concerns	Institutional Concerns	Other Concerns	Time
CM-1 No Action	0.0	0.95	• Minor implementation hazard. • Minimal health risk.	• Low vertical-core contaminated sediment remains at site. • Construction Marsh sediment may not be a sufficient source of OM, CB & DR to cause bioaccumulation and toxicity. • New sediment may cover the contaminated sediment to eventually reduce vertical loadings of residual and transient biota.	-			
CM-2 Hydraulic Dredging Thickening Filtration Offsite Disposal	54.59	71.25	• Major implementation hazard.	• Remove most contaminated sediments. • More immediate elimination of vertical contamination of residual and transient biota. • Severe disruption of habitat for important species. • Marsh restoration may be difficult and require further disruptive activities. • Minor modifications of flow pattern during implementation.	• High effectiveness. • Heavy Construction traffic. • Proven technology	• Consumes offsite sanitary landfill capacity.	• Truck traffic. • Difficulties in marsh restoration	7 years
CM-3 Hydraulic Dredging Thickening Dewatering Off-Site Disposal	72.83	77.17	• Same as CM-2	• Same as CM-2	• Same as CM-2	Consumes offsite hazardous waste landfill capacity.	• Same as CM-2.	7 years

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Table 14
Continued

SUMMARY OF ANNUAL OPERATIONS AND MAINTENANCE COST ESTIMATES
(1986 Dollars)

Alternatives	Annual O&M Cost ($1000/Yr)	Operation and Maintenance Duration (Year)
East Foundry Cove Marsh (ECM)		
ECM-1 No Action	54	1-30
ECM-2 Hydraulic Dredging/Thickening Fixation/Off-Site Disposal	3,430	1 year
	80	2-5
	27	6-30
ECM-3 Hydraulic Dredging/Thickening Fixation On-Site Disposal	3,184	1 year
	137	2-5
	84	6-30
ECM-4 Hydraulic Dredging/Thickening/ Dewatering/Off-Site Disposal	778	1 year
	80	2-5
	27	6-30
ECM-5 Containment	200	1-5
	148	6-30
Constitution Marsh (CM)		
CM-1 No Action	100	1-30
CM-2 Hydraulic Dredging/Thickening Fixation/Off-Site Disposal	8,806	1-2
	499	3-5
	79	6-30
CM-3 Hydraulic Dredging/Thickening/ Dewatering/Off-Site Disposal	1,768	1-2
	499	3-5
	79	6-30

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Table 15